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ABSTRACT

This report, on science education in the United States, East Germany, West Germany, China, Japan, and the USSR, has 12 chapters. Chapter 1 presents an overview of precollege science education in the United States from 1940 to 1970. In chapter 2, the status of science education from 1970 to 1980 focuses on elementary and secondary school science instruction, trational science curriculum, science instruction in all the countries, and science enrollments and school requirements. Chapter 3 presents information on science facilities. Chapter 4 summarizes findings about science teachers, problems of science teacher supply and demand, and inservice education and professional development for science teachers. In chapter 5, a comparison is made between nonschool science education in the United States and the selected foreign countries, and similar comparison is presented in the 6th chapter on instructional practices in science teaching. Science achievement and students' attitudes toward science are compared in the 7th chapter. The discussion in chapter 8 deals with differences and similarities of parental attitudes toward science education in the United States and other countries. A global view of research and development in science education is offered in the 9th chapter. In the 10th and 11th chapters, problems, issues, and concerns in science education in the United States and actions being taken are examined. The final chapter offers a synoptic overview of science education in foreign countries. (JD)

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AN OVERVIEW OF SCIENCE EDUCATION IN THE UNITED STATES AND SELECTED FOREIGN COUNTRIES

by

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AN OVERVIEW OF PRECOLLEGE EDUCATION IN THE SCIENCES IN THE UNITED STATES

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Part I

Chapter 1. Science Education in the United States: 1940-1970

The present concerns about science and technology education in the American schools are longstanding. Serious efforts to initiate improvements have been underway since the close of World War II. In 1947 the President's Scientific Research Board asked the Cooperative Committee on Science and Mathematics Teaching of the American Association for the Advancement of Science to study the condition of school science teaching. The Committee's study was incorporated in a comprehensive report on Manpower for Research authored by the President's Scientific Research Board (1). Among the conditions identified by the Committee were:

- There is a serious shortage of high school teachers of science and mathematics and a rejection of science

teaching as a career by college students. Science graduates in universities are more attracted to positions in industry, government, business, and college teaching.

- The teacher shortage has led to the employment of unqualified teachers, overcrowded classes, and the decreased effectiveness of science instruction.
- The teacher shortage is largely an economic problem not only in terms of teacher salaries but also of the general support of education. Schools must be able to compete with salaries in industry in order to attract teachers well qualified in mathematics and the physical sciences.
- The management of laboratory equipment and non-teaching duties lessens the attractiveness of science teaching as a career.
- Only about 7 percent of the total high school students at any one time are enrolled in physics or chemistry. Because of small enrollments in science, science teachers must teach other subjects as well.

In 1953, a conference on nationwide problems of science teaching in the secondary schools was held at Harvard University at the invitation of James B. Conant, then president of Harvard. A report of the conference pointed to the decreasing availability of science teachers at the very time school enrollments were increasing (2).

Other state and national committees noted that an increase in the number of science teachers would not resolve the problems of science education unless teachers were properly trained. There was general agreement that the training program for science and mathematics teachers, to be most effective, must be a specifically planned professional program extending through at least one year of graduate work.

After the successful ortiting of a Russian space probe in October 1957 the quality of science education in the U. S. was again questioned. In January 1958 the U. S. Congress began hearings "to learn, in the light of recent Russian scientific and educational achievements, what action America must take to strengthen our education." There were 22 days of hearings on the subject of "science and education for national defense" before the Committee on Labor and Public Welfare, United States Senate, leading to 1600 pages of testimony (3). Testimony was obtained from representatives of the National Academy of Sciences, the National Science Foundation, the American Association for the Advancement of Science, leading scientists, Secretary of Health Education and Welfare, major educational associations, colleges and universities, engineering societies, and labor groups, altogether 96 organizations. In addition, verbal or written testimony was obtained from several hundred individuals representing schools, government, business or industries. The tenor of the testimony was the need to 1) strengthen student financial support for careers in science;

2) develop programs for gifted and talented students; 3) update the science curriculum; 4) upgrade teachers and teacher education; 5) develop a closer alliance between schools and colleges; and 6) improve science facilities and modernize equipment.

At the hearing, testimony on enrollments in secondary school science was presented (4). It was noted that in the fall of 1956, 67 percent of the students were taking general science in grade 9; 73 percent taking biology in grade 10; 32 percent taking chemistry in grade 11; and 24 percent taking physics in grade 12. In terms of the total secondary school (grades 9-12) enrollment, the number of students taking general science was 21.8 percent, biology 21.5 percent, chemistry 7.5 percent, and physics 4.4 percent. Eighteen percent of the high schools with a 12th grade offered neither physics or chemistry; however, 95 percent of all 12th grade students in the U. S. could have had a course in physics or chemistry. All science courses in high school enroll more boys than girls except biology, where the numbers are about equal. In physics courses the percent of boys was 78 and in chemistry 58. In the northeast states, including New York and Pennsylvania, twice as many students (35.3 percent) in the 12th grade take physics compared to the west coast states (16.9 percent).

Enrollments in mathematics in 1956 were as follows: 9th grade, 33 percent of the students taking general mathematics and 67 percent elementary algebra; 10th grade, 42 percent taking plane geometry;

11th grade, 32 percent taking intermediate algebra; 12th grade, 9 percent taking plane trigonometry and 8 percent solid geometry. By the time of graduation from high school, two-thirds of the students have had a course in elementary algebra, one-third in intermediate algebra, two-fifths in plane geometry, and about one-eighth in solid geometry and trigonometry. The number of boys exceeded the number of girls only slightly in required mathematics courses. By the 12th grade, the ratio of boys to girls in math is nearly 4 to 1. The percent of students taking intermediate algebra, solid geometry, and trigonometry was greatest in the southern states (approximately 40 percent) and least (10 percent) in the Pacific states.

The pressures for a reform of science education gained momentum in the last years of the 1950s. Private foundations, educational organizations, citizen groups, concerned scientists as individuals and as members of professional societies, and agencies of the federal, state, and local governments developed statements on what should be done about science and mathematics teaching in particular and education in general in the U. S.

The issues that emerged focused on the need for 1) "quality" or "excellence" in education, 2) the improvement of science and mathematics curricula, and 3) increased educational opportunities for gifted and talented students (5).

The growing criticism of science education in schools by scientists and the public alike focused on a demand for a curriculum reform beginning in the secondary schools. The National Science Foundation set up an organizational unit in 1957 to consider proposals for science curriculum improvement at the precollege level. Government funds were made available to improve existing science courses (biology, chemistry, physics), not to create entirely new courses that would have to compete for a place in the secondary school curriculum and perhaps violate the traditional local right of schools to choose their own curriculum.

Policies for the Federally supported curriculum projects evolved over a period of several years and included: 1) more than one new course should be developed for each science subject; 2) the project team must be composed principally of competent research scientists; and 3) responsibility for the character of the new course was to rest with the scientist team. Policies about the publication of the new courses, their revision, and implementation were established at a later time.

While the project teams for physics, chemistry, biology, and earth science worked independently, certain commonalities emerged in their approach to curriculum development including 1) the selection of subject matter, 2) the context of the curriculum, 3) the organization of courses, and 4) teaching procedures. There was a consensus that a high school course should be a modern representation of a discipline

as scientists know that discipline. The subject matter should be up-to-date in terms of the knowledge and theories that comprise a discipline. Aspects of relevant technology were not considered to be a part of a science course. The subject matter should be limited to a few overarching conceptual themes significant for understanding the intellectual base of a discipline. Scientific concepts which appear early in a course should have meaning for what is to be learned later. Science should be taught as a system of inquiry with an emphasis upon its intellectual processes and quantitative methods. Laboratory and field work should embody elements of scientific methodologies and provide opportunities for students to investigate and discover facts or laws for themselves. Wherever possible the results of an investigation should be expressed in quantitative terms. In presenting a course every effort should be made to transfer the responsibility for learning from the teacher to the student, one reason for the emphasis on laboratory and field work (6).

The movement to reformulate the teaching of science in the elementary school began in the 1960s. The major criticisms of existing elementary science programs were: 1) they did not represent "good" science; 2) they were mostly "reading" courses; 3) "activities," disguised as experiments, were more characteristic of a magician show than of science; and 4) many of the topics taught were conceptually, as science, beyond the intellectual grasp of children.

The National Science Foundation (NSF) supported the development of twelve elementary school science programs because there was little consensus as to what children might be able to learn from the study of science. Each of the projects funded differed from most conventional courses in rationale and subject matter. Each of the innovative elementary school science programs also differed from each other in subject matter and organization. Since no one was quite sure how science should be taught to children NSF favored projects that proposed reasonable and interesting new approaches to teaching the subject. Later the very diversity of these programs would prove to be a negative factor in their adoption by schools. School administrators and teachers did not comprehend the significance of these experimental courses for the learning of science (7).

Although differences existed among the new elementary school science programs there were commonalities. Each curriculum was designed to provide for six years of instruction, grades one through six. There was an effort to provide for a progression in conceptualization and reasoning skills from grade to grade. The number of physical science topics presented was greater than found in the traditional courses. This was an effort to provide an integrated view of science rather than courses defined by single disciplines. In all the programs the method of instruction emphasized was that of "discovery," of engaging children in learning activities from which they could "find

out things for themselves," sometimes described as a "hands on," "messing about," or "process" approach. The objective was to involve the pupil directly in learning in the manner characteristic of scientists such as observing, measuring, inferring, and related skills. It was thought desirable that whatever science the children were taught should be "good" science so that there would be no need to correct the learning unless science itself changed at a later time. Any reteaching of a concept, and this was felt desirable, should be to extend its meaning. In different degrees the learning of science was combined with some learning or application of mathematics concepts.

The development of new science courses designed specifically for the junior high school (grades 7, 8, 9) occurred late in the science curriculum reform movement. The last science curriculum project supported by NSF, the Human Sciences Program developed by the Biological Sciences Curriculum group, was completed in 1981 and marked the closed of the curriculum improvement projects. From 1960 to 1970 a number of innovative science courses were developed for use primarily in the ninth grade, such as "Time, Space, and Matter," "Earth Science Curriculum Project," "Introductory Physical Science" and others. In practice, some of the elementary school science materials considered too difficult for elementary school children were used in grades seven and eight.

Typically two types of science programs are taught in junior

high schools, one a three-year integrated general science offering and the other a three-year sequence of discipline oriented courses--life, physical and earth science--each course independent of the others. Two junior high school innovative science programs completed in the 1970s, the Intermediate Science Curriculum Study (ISCS) and the Human Sciences Program (HSP), are different in educational concept from earlier NSF supported projects. Both of the courses of study were designed to integrate various sciences into a program of general education (8). Students were expected to develop a command of basic science concepts, their interconnections and applications in everyday affairs. Courses were organized to engage students in a wide range of problem situations that require them to use intellectual skills characteristic of both inquiry and decision making. Particular attention in these programs was given to selecting subject matter which was comprehensible by early adolescents as well as effective in attracting their interest. These programs were constructed in a way that makes it possible to individualize instruction to a greater extent than conventional science programs for use in junior high schools.

In addition to complete science courses and programs financed by NSF, instructional aids of various types were produced by business and industry, such as, science career guides, films, and booklets on simple experiments. The National Aeronautics and Space

Administration and the Atomic Energy Commission developed curriculum and special topic science booklets. Professional scientific and engineering societies produced career guides and pamphlet materials on recent scientific advances. Federal support was provided for the invention or improvement of science equipment, such as a device for projecting chemical experiments, a climate house for biology experiments, inexpensive microscopes, and science kits for use in elementary schools. A separate television series was produced for physics, chemistry, and biology designed to up-date the knowledge of teachers planning to teach the "new" science courses. These were telecast nationally under the series title Continental Classroom. The advent of the 16mm "loop film" created a new wave of film programs suitable for use by individual students. Programed textbooks, adopted from industrial training programs, were written for "slow learners" and "self-study" students. As early as 1965 computers began to make their way into science classes. Mobile science laboratory carts and demonstration tables were manufactured for classrooms where science facilities and equipment were not available. These are but samples of the range of instructional materials prepared to improve the teaching of the new science courses.

The wide publicity given to the science curriculum improvement projects stimulated toy manufacturers to develop an array of science toys and kits for home use. Sales in trade books on science boomed. Publishers selling science textbooks added films, filmstrips, slides, large display charts, and kits to their book line. In general, the

materials produced were factually accurate in terms of science, but not always consistent with the educational rationale underlying the revised curriculum programs. This led to the formation of consumer-type agencies and science teacher committees who sought to evaluate the educational worthiness of the vast array of products on the market for teaching science.

It was evident from the onset of the science curriculum reform that schools would need financial aid for modernizing their science programs. On September 2, 1958, President Eisenhower signed into law the National Defense Education Act (NDEA). Title III of the Act specified that Federal funds, on a matching basis, could be obtained by schools for the:

> ... acquisition of laboratory and other special equipment and printed materials (other than textbooks), suitable for use in providing education in science, ... minor remodeling of laboratory or other space used for such materials or equipment; ... (9).

Entering the 1960s the Federal responsibilities for improving science education were rather clearly defined. The National Science Foundation would be responsible for the development of instructional materials and for the retraining of teachers. The United States Office of Education, with the authorization of the NDEA, would help schools to develop science facilities and obtain equipment. Additional assistance to schools was provided by professional societies, private foundations, and by business and industry. For example, the American

Association for the Advancement of Science established a network of "traveling libraries" of a hundred or so science books each, that schools could borrow. The collection included books for teachers as well as for students. The National Science Teachers Association developed a "packet service" for the free distribution of teaching aids developed by industries.

It was evident from the beginning of the science curriculum improvement movement that without teachers who were up-to-date in their knowledge of science and informed about the new science courses little improvement in science education would be achieved. Beginning in the late 1950s and continuing until the mid-1970s, NSF supported a variety of teacher education programs including 1) summer institutes, 2) inservice programs, 3) academic-year institutes, and 4) conferences. About 85 percent of the participants in these programs were secondary school science teachers and supervisors.

During the peak years of the program, 1959-1972, approximately $35,000,000 per year was spent for precollege science teacher education. In 1965 for example, 35,244 secondary and 4,116 elementary teachers were accommodated in NSF precollege teacher education programs in science and mathematics at a budget figure of $43,000,000. Of the estimated 226,000 secondary school science and mathematics teachers in the U. S. at the time (1959-1972), about 40 percent participated in one or more re-training programs. It is generally believed that the teachers needing retraining the most were the ones who did not participate in the various programs. The Shell Companies

Foundation, Westinghouse, and General Electric and other companies also supported retraining programs for science teachers.

Materials were developed that could be used by teachers for self-education. Several of the curriculum projects--physics, chemistry, and biology--produced a series of training films tailored more or less to the corresponding "new" courses. Some of the films illustrated teaching techniques and others focused on subject matter. Elaborate teachers' guidebooks or handbooks were written to accompany the innovative textbooks. Typically, they served to acquaint teachers with subject matter, provided suggestions for instructional practices, and included tests and answers to problems, as well as sources of teaching materials.

Science teachers' associations devoted a substantial part of their convention time to workshops on teaching the new science courses. Commercial exhibitors at these meetings featured equipment associated with the innovative science programs and staffed demonstration sessions. An unknown number of state and local inservice programs, workshops, and demonstration centers were initiated by science supervisors; most of these programs were for elementary school teachers. A number of colleges and universities established science teaching centers where teachers could get help in using the different programs.

It was widely recognized by educators and scientists that if science teachers were properly educated in the colleges and universities as undergraduates the need for retraining programs would be less.

The American Association for the Advancement of Science (AAAS), with the financial support of NSF, and in cooperation with the National Association of State Directors of Teacher Education and Certification, in 1971 issued a report on guidelines and standards for the education of secondary school teachers of science and mathematics (10). Guidelines and standards were published in 1963 and in 1970 with recommendations for the preservice science education of elementary school teachers (11). The purpose of these guidelines was to suggest how the preservice education of science teachers could be brought into line with the newly developed innovative elementary and secondary school science programs.

The status of college programs for the preparation of science teachers was examined in 1968 in a survey of 725 colleges and universities (12). The study revealed that future science teachers for high schools were not being prepared to teach the innovative science courses. Less than half of the college teachers of science methods courses pay any or only minimal attention to the "new" science programs. These instructors expressed concern over the practical difficulties of teaching the "new" courses and their limited use in the schools. It should be noted that at no time during the curriculum improvement movement were programs supported for informing teachers of teachers about the new developments.

Democratic policies in public education have typically been interpreted to mean the same education for all students. In 1959 the President's Science Advisory Committee stated a different point

of view: "In America we try to offer opportunities to all to the degree they can grasp them..." and for each to "develop his own talents to the fullest...we should take immediate and greater steps to speed the discovery of talent, and to encourage and support that talent when it is found." This statement, released from the White House May 24, 1959, set the policy for the Federal support of programs for the gifted and talented in the sciences (13). NSF began the financial support of special summer programs for talented high school students in colleges and universities, and fostered a variety of school science projects designed for gifted students. Professional scientific societies also established ways to help gifted students. The American Chemical Society established a plan whereby selected members agreed to devote at least 30 hours per year helping students with science projects. The Biological Science Curriculum Study (BSCS) developed four volumes of original research problems that potentially could be solved by a good high school student. The BSCS rationale was that talented students should be challenged with learning activities commensurate with their ability. The scientists who suggested the problems agreed to respond to questions students might direct to them. A number of industries provided summer employment for gifted students to work in their laboratories as assistants. Grants from the Ford Foundation, the Carnegie Corporation, and other donors had established in 1955 a National Merit Scholarship Program to provide "assistance to students of exceptional ability" to attend a college or university of their choice. The Science Clubs of

America sponsored a National Science Fair for students to display and discuss the results of their research with scientists. An Annual Talent Search program, in cooperation with the Westinghouse Educational Foundation, awards college scholarships and cash prizes to high achieving students who complete research projects. The AAAS established a "congress" at its annual meeting exclusively for selected high school science students. At these meetings students heard reports from scientists and had opportunities to examine equipment and books, and view films on science and technology.

In 1970 the U. S. Congress requested a report from the U. S. Office of Education on: 1) the success of programs for the gifted and talented children; 2) the extent of these programs; and 3) the possible needs for new programs. Findings from the USOE study indicated that the Federal role in the delivery of services to the gifted and talented had all but ceased and there was a "widespread neglect of gifted and talented students" (14).

Summary, Part I

This overview of precollege science education covers the period from the beginning of the science curriculum reform movement in the mid-1950s to the 1970s. In this period of time occurred America's greatest effort to reform science education in the schools. Innovative curricula were developed and massive efforts made to retrain teachers to implement the new science courses. The Federal Government provided funds to improve teaching facilities and to purchase equipment and supplies essential to the proper teaching of

the innovative courses.

The perceived need for high level scientific and technical human resources to maintain America's scientific and economic progress made the science education of gifted and talented students a priority. Programs for gifted students flourished in the early 1960s but received less and less attention as the decade progressed.

The major thrust for the reform of precollege science education came primarily from the scientific community. Scientists designed the new curricula, selected the subject matter, and devised the laboratory experiments. Their primary goal was to present an up-to-date and conceptually accurate interpretation of the structure of various disciplines and to convey an understanding of their investigative processes.

Science departments in colleges and universities were funded to offer a variety of programs designed to update the science background of teachers in terms of new course demands. Scientific societies as well as individual scientists assisted in may ways to assure the success of the Federally supported courses.

For the years 1957 through 1980 the National Science Foundation allocated a total of $839,330,000 for the improvement of precollege education in the sciences and mathematics(15). Added to NSF funding, the amount of money contributed by NDEA on a matching basis to states brought the investment for improving science and math education to over one billion dollars.

Early in the 1970s it was apparent that for some known, and perhaps more unknown reasons, precollege science education in the schools of the U. S. at all educational levels was in a predicament. The developing crisis in science education during the 1970-1982 period is examined in Part II of this report.

Part II

Chapter 2. The Status of Science Education: 1970-1980

Science Course Offerings: The Elementary School. Science is taught in nearly all elementary schools, grades kindergarten through six. Approximately 25 percent of the states and 46 percent of school districts set guidelines for the minimum amount of time for science instruction. Teachers report they average 17 minutes per day for science in grades K-3, and 28 minutes in grades 4 through 6 (16). The time devoted to science teaching is less than for social studies, mathematics, and reading.

The science program in elementary schools consists of an integrated series of textbooks, one for each grade level. These texts are usually written with a senior author who has a science background, in collaboration with separate authors for various grade levels who are specialists in reading or children's learning. Schools adopt textbooks as a series covering six grades, rather than separate books for each grade level.

In 1982, there were 31 series of elementary school science textbooks on the market. In addition, there were hundreds of single title books written for use in elementary schools, such as books on plants, fire, water, fish, clouds, rocks, nature study and others which teachers could use to build their own course of study (17).

In grades 1-3, 10 textbook series account for 40 percent of the market in elementary schools where science is taught. The leading text is used in 12 percent of the schools, the second ranking text in 5 percent. Of the commonly used textbooks, the Federally supported programs are used in 8 percent of the classes. In grades 4-6, 12 text series account for two-thirds of all class usage. The two leading text series are used in 16 and 10 percent of the classes respectively. Four Federally supported science programs together account for 11 percent of the class offerings in science (18).

Science Course Offerings: The Junior High School. There are two major types of science offerings in grades 7, 8, 9. One is an integrated general science sequence of three years, and the other a discipline-centered program consisting of one year each of life, physical, and earth science. In some states a health requirement is likely to displace one of the science courses. In the ninth grade, high school biology may be taken by the more advanced students, or those planning a four year sequence of high school science. The number of schools offering the two major sequences is about equally divided. The traditional offering in the junior high school from 1915 to 1960 had been general science. General science was originally designed to introduce students to a variety of sciences in the hope that this would stimulate interest in taking more science in the secondary school. The discipline based courses were introduced into the curriculum in the 1960s as part of the Federally supported science curriculum improvement

programs. The rationale of the developers was that a science should be explored in depth to have any meaning for education.

In 1982 there were 12 general science series, 16 life science, 18 physical science, and 27 earth science textbooks available for use in junior high schools. These numbers do not include senior high school textbooks that may be used for advanced science courses in the junior high school. Only one textbook, an earth science book, is used by as many as 8 percent of the science classes. Thirteen textbooks comprise the offering in 48 percent of the junior high school science classes. Of these texts, 2 represent the new science and were taught in 11 percent of the classes. Six different texts comprise the life science offering and represent 15 percent of all junior high school science classes. General science textbook series were used in 19 percent of the junior high school science classes.

Science Course Offerings: Senior High School, Grades 10-12. The standard course offerings in the senior high school are biology, physics, chemistry, and to a lesser extent physical science. Textbooks available for these courses include: 43 for biology, 49 for chemistry, 28 for physics, and 4 for advanced physical science. In addition, there are college textbooks, slightly rewritten and shortened, for use at the secondary school level including 16 in chemistry and 3 for physics. The college texts are typically used for advance placement or honors courses. In the biological sciences there are 16 advanced high school texts emphasizing microbiology, biochemistry, genetics or ecology, and 14 texts for high school anatomy and

physiology courses. Of the 13 most widely used science textbooks in grades 10-12, 8 are biology books. The biology texts written with Federal support (BSCS) are used in 12 percent of classes and commercially authored texts in 22 percent of classes. In physics two non-federally supported books make up 6 percent of class use. The only commonly used Federally supported physics textbook is used in 2 percent of classrooms. Only one textbook in chemistry, a non-Federally supported text, with 7 percent class use, appears on the list of most frequently used high school science texts. The remaining text on the list of most-widely-used is a physical science text with a 2 percent usage (19).

The number and diversity of textbooks at every grade level preclude any notion that there is a common curriculum in the sciences in American schools. They also preclude any clear notion of what the average student is learning in science, and whether it is "good" or "bad" science. Because scientific information is universal in fact and theory we can assume that most students taking biology will learn something about photosynthesis, chemistry students will be exposed to the periodic table, and those in physics will learn about wave motions. Differences between texts are more along these lines: the way topics are conceptually dealt with, whether topics are up-to-date, accuracy, sequencing and emphasis, extent of mathematical treatment, vocabulary control, writing style, visuals, format and support materials such as student tests, films, workbooks, and laboratory manuals.

The Federally funded textbooks in science, while not widely used in schools, have exerted an influence on commercially produced textbooks in the same subject. While there has been only limited study of the secondary impact of the innovative science programs, they have had an influence on standard texts (20). Following publication of a Federally supported text, commercial books in the same field were found to: 1) update and readjust subject matter to reflect the discipline as it is portrayed in the innovative text; 2) organize the subject matter around large ideas or conceptual themes characteristic of the innovative programs; 3) incorporate identical or similar laboratory experiments; and 4) increase the number of laboratory activities in the text. The innovative curricula in unmeasurable ways set new standards for scientific validity and significance of science concepts in school textbooks. The sales of Federally supported science texts peaked in the early 1970s. When publishers found these books to be no longer commercially competitive some dropped previously accepted innovations on the assumption teachers preferred traditional materials.

<u>Changes in the Traditional Science Curriculum.</u> Beginning in the late 1960s and accelerating during the 1970s a number of new science courses were added to the curriculum in the junior and senior high schools. For example, courses in earth-space sciences (a combination of astronomy, meteorology, aeronautics, earth and space geology, oceanography) increased from an enrollment

of 76,564 in 1960-61 to 1,233,434 in 1972-73, or 6.6 percent of total science enrollments (21). Courses in environmental science, ecology and conservation increased during the 1970s, along with offerings in energy, metric measurement, applied sciences, drugs and alcohol, sex education and a host of others. Many of these new subjects were described as mini-courses indicating they were less than a semester in length. These additions to the science curriculum were typically a response to student demands or public pressure. An assortment of advanced science courses such as biochemistry, air pollution chemistry, human development, human genetics, and microbiology also increased in number. Vocational or technical educational subjects, such as science equipment repair, applied electricity, urban horticulture, and electronics were additional science offerings. There has not been a nation-wide study of the extent and variety of these additions to the school science curriculum but a reasonable estimate of the number would be in excess of 100 titles. The declining enrollments in the traditional subjects of biology, chemistry, and physics may have been compensated for by the increased enrollments in new science offerings.

Some observers view the proliferation of school science courses as a dilution of efforts to effect a philosophically sound basis for a general education in the sciences for all youth. Their recommendation is that these "special" courses be dropped from the

school curriculum (22). Other observers believe course diversification is an essential feature for education in a democratic society and support expanding course offerings. However, a 1981 survey of minicourse offerings, limited to mid-western states, showed an 87 percent reduction in science minicourses since 1976 (23). The decline is possibly due more to economic conditions in schools than to a change in philosophical beliefs.

The Foreign Experience in Science: Course Offerings. Science as a scholarly endeavor is universal in terms of its theories, laws, constructs, facts, and investigative criteria. What is not common in schools is the status of science in the total curriculum, course offerings, and requirements for graduation. Other differences will be considered in later sections of this report and in the final chapter. The high technology countries of Japan and the Federal Republic of Germany (West Germany) provide an interesting contrast in science offerings and requirements.

West Germany education, like the U. S., is characterized by its diversity. In the primary grades (1-4) all children are introduced to biology, chemistry, physics, and geography. At age 10 a choice must be made between attending a school with a prevocational orientation (Hauptschule); or one oriented to mid-level careers in industry, business, and government (Realschule); or a university preparatory academic school (Gymnasium). Science requirements

vary by type of school and by states, there is no national curriculum. In a typical Hauptschule (Northrhine Westfalia) of 10 grades, science is required in grades 5 through 10 and technical instruction in grades 7 through 10. The Realschule in Lower Saxony requires 10 periods of biology and 8 of physics spread over grades 5 through 10, and 4 of chemistry spread over grades 8, 9, 10. The Gymnasium in the state of Hesse requires 10 periods of biology over a 5-year period and 6 each of chemistry and physics over a 3-year period (24).

In Japan, science in the elementary school is required 2 hours per week in grades 1 and 2, 3 hours per week in grades 3 and 4, and 4 hours per week in grades 5 and 6. In the junior high school (grades 7, 8, 9) the science requirement for all students is 4 hours per week at each grade level and consists of introductory topics in biology, physics and chemistry. In the standard senior high school (grades 10, 11, 12) all students are required to take 5 credits (a credit equals 35 school hours) of physics, 4 of chemistry, 4 of biology, and 2 of earth science (25).

The Communist countries of China, USSR, and East Germany have about the same offerings and requirements in school science. The USSR syllabus for Soviet general education schools will be used as an example. These schools at present have ten grades. Nature study is a required course in grades 2, 3, and 4 for 2 days per week. Beginning in grade 5 and continuing through grade 10 biology is required 2 days per week. Students begin physics in grade 6

where the requirement is 2 days per week and the same for grade 7. In grades 8, 9, and 10 the hourly requirement per week for physics is 3, 4, and 5 respectively. Chemistry begins in grade 7 and meets 2 periods per week in grades 7 and 8, increasing to 3 periods in grades 9 and 10. A period of astronomy is required in grade 12 (26). If geography is regarded as a science, the requirement in junior and senior high school years is equal to that of biology in both communist and high-technology countries.

In the school science program of foreign countries, elective subjects are rare and when offered are scheduled for the last year of high school. Science is required of all students and at every grade level. Courses extend over a period of several years; however, they rarely meet 5 days per week. Based on the total number of class hours devoted to science in a three-year foreign high school <u>all</u> students will have had approximately 3 times as many class hours of science as a student in the U. S. who elects to take 3 years of science in high school.

Science course offerings, student selection of courses, and enrollment figures in the selected foreign countries are not educational issues because science is required of all students. There are practically no electives and where available they are in addition to the required program. Under these educational conditions it can reasonably be expected that the general level of scientific literacy among foreign school graduates is higher than in the U. S. The course enrollment figures for science in the U. S. are presented in the next section of this report.

Major Science Course Enrollments in Junior and Senior High Schools. The diversity of science course titles, the lack of standard grade level course offerings, conflicting figures on enrollment information depending on the source (whether school administrators, teachers, or students), and sampling techniques limit the reliability of enrollment figures (27). What is reported here are estimates and approximations based on information abstracted primarily from the three most recent national surveys of science enrollments (28).

Total science enrollment for grades 7-12, in 1972-73 was 67.2 percent of all students in school. This is a slight increase over the school year 1960-61 in which 66 percent of students were taking science courses. In the junior high school (grades 7-9) approximately 70 percent of the students are enrolled in a general science sequence and 30 percent in a program consisting of separate courses in earth, life, and physical science. Enrollment in life science is about 20 percent higher than for either physical or earth science. The number of students in ninth grade general science is only 18 percent of those taking the course the previous two years. Because the general science sequence is an integrated program of three years the number of students in the ninth grade taking the course should approximate grades 7 and 8. Based upon the total enrollment for grades 7-9 it appears that at least 75 percent of the students in the junior high school complete two years of science.

Science enrollments for the senior high school (grades 10-12) show that approximately 66 percent of the students take a beginning biology course. Almost 25 percent of these students will complete a second course in biology during their junior or senior years. By graduation time approximately 35 percent of the seniors will have taken a course with the title of chemistry, and 19 percent a course with a physics title. It appears that approximately 9 percent or fewer of graduating seniors will have had a course in "classical" or "traditional" physics as distinct from applied physics or advanced physical science. In addition to these major science courses an unknown number of students will also have taken one or more courses in aeronautics, oceanography, zoology, astronomy, or other titles. Based on an approximation of 9 million students enrolled in grades 10, 11, and 12 for the school year 1967-77, 2.6 million were taking a biology course, 1.19 million chemistry, and 469,000 physics (29).

The National Science Teachers Association compiled data on the number of science classes being offered in secondary schools (grades 7-12) per 1000 students enrolled in public schools (30). These data indirectly represent approximate enrollments in different sciences as well as the relative emphasis given each science.

NUMBER OF CLASSES PER 1000 STUDENTS

Physical Sciences		Biological Sciences	
Chemistry	4.46	Biology	8.79
General Science	4.10	Other Life Science	1.16
Geology/Earth Science	2.19	Anatomy/Physiology	0.68
Physics	2.16	Environmental Science	0.49
Other Physical Science	1.99	Ecology	0.23
Astronomy	0.17		
Total	15.07	Total	11.35

Because general science courses contain considerable biology the emphasis on physical and biological science is about equal.

A study of college bound seniors for 1981 revealed that these students had taken 1.40 (mean total) years of biological sciences and 1.79 (mean total) years of physical sciences (31). The number of courses in the physical sciences taken by the 1981 college bound seniors is the largest ever.

The years of science taken by students graduating from a high school varies with the type of curriculum pursued. For students in an academic curriculum 74 percent will have taken two years and 55 percent three years or more of science. Two or more years of science will have been completed by 44 percent of the 35 percent in the vocational curriculum. These figures drop to 13 percent and 9 percent respectively for students with three years of science. Of the college bound seniors in 1980-81, 9.2 percent took

an honors course in the biological sciences and 9.6 percent in the physical sciences. In 1981, college bound high school seniors had taken more courses in the physical sciences and mathematics than students in any previous graduating class (32).

School Requirements in Science. At the elementary and junior high levels science is a requirement in 98 percent of the schools. Arithmetic is a requirement in 100 percent of the elementary schools and mathematics in 99 percent of junior high schools. In senior high schools biology is a required course in 44 percent of the nation's schools and an elective in 55 percent, only 1 percent of schools do not teach the course. In addition to biology another science course is required in 60 percent of high schools. The second course is not necessarily a physical science course but can be a second year of biological science. Only 1 percent of high schools fail to offer two or more science subjects. A course in mathematics is required in 91 percent of high schools. More than 90 percent of schools include metric, alcohol, and drug education in established courses rather than in separate courses. Environmental studies and sex education are separate courses in 10 percent of high schools and offered as integrated topics in 87 and 82 percent respectively (33).

School programs for gifted and talented students in science largely take place in honors and advance placement courses. Science fair competitions and national contests, such as the Westinghouse Talent Search and the National Merit Scholarship program are outcomes

of instruction, not part of the school curriculum. The number of students taking advanced placement courses has increased from 24,300 in 1969 to 49,600 in 1979 and in every year the national mean scores on the standard achievement test for science have increased over those of the previous year (34). Nationally, 9.2 percent of the one million students taking the Scholastic Aptitude Test had participated in an honors course in biology and 9.6 percent an honors program in the physical sciences (35). The number of graduating seniors for the 1980-81 school year was 3,000,000 with about half in transition to approximately 3,000 colleges. Girls take more honors courses in the biological sciences than boys and the reverse is true for the physical sciences.

Chapter 3. Physical Resources for the Teaching of Science

Science courses require adequate facilities (laboratory space, utilities, and furniture), equipment (balances, microscopes, telescopes), and supplies (chemicals, living specimens, batteries) for effective teaching. Equipment over a period of time wears out and supplies are expendable requiring an on-going budget for replacements. When these materials are in short supply, what is available is used by teachers for demonstration lessons. When materials are adequate, students have an opportunity to engage in group or individual laboratory activities (36).

Science Facilities: Elementary Schools. Only 4 percent of K-6 schools have a special room where science is taught; 54 percent make do with portable carts containing equipment and supplies.

Although 36 percent of the elementary schools have no facilities or equipment for teaching science, only 35 percent of the teachers surveyed felt a need for improving conditions. In 1977, only 16 percent of elementary schools had a specific budget for science equipment and 20 percent a budget for supplies. Those schools with a science budget allocated $4.61 per pupil per year. One can expect to find models (solar system, biological) and a microscope in approximately 75 percent of the elementary schools; less than 10 percent have a computer or access to a terminal; however, 75 percent of the teachers felt there was no use for computers in the elementary school and in only 2 percent of the schools with computers did children use them.

Science Facilities: Junior High Schools. Rogers (37) reported in 1967 that in about seven out of ten junior high schools, science was taught in a combination classroom-laboratory arrangement; 10 percent of schools had separate class and laboratory rooms and 25 percent had no laboratory facilities. Schools with specific budgets for equipment and supplies in 1977 averaged $8.70 per pupil. Although 16 percent of grade 7-9 schools have access to a computer, 84 percent of the teachers see no need for the equipment, and 1 percent make use of it. Fourteen percent of teachers would like access to a computer. About 40 percent of junior high teachers feel their facilities and equipment for teaching science need improvement.

Science Facilities: Senior High Schools. Separate class and laboratory rooms, or a combination class-laboratory arrangement, are found in 90 percent of the secondary schools (38). In 1977 36 percent of high schools had computers or computer terminals available for science instruction, but only 16 percent of the teachers saw a need for the equipment; and 9 percent used it. In 1982, 60 percent of secondary schools had microcomputers available for instruction and an additional 18 percent had terminals. The major uses of microcomputers in schools (not necessarily for science instruction) were teaching computer science (49 percent), developing computer literacy (39 percent), learning enrichment (18 percent), teaching basic skills (12 percent) and remedial instruction (6 percent). The major use of terminals for instruction was in the same order of frequency as for microcomputers (39).

Thirty-six percent of high school science teachers indicate their science facilities, equipment, and supplies are inadequate. Science teachers at all educational levels (58 percent) see their major need to be money for laboratory assistants, and (53 percent) money to buy supplies on a day-to-day basis. For the school year 1976-77 about half of the school districts received Federal funding for science equipment and supplies. Most of these funds were provided through the National Defense Education Act and Elementary and Secondary Education Act (40).

A wide variety of audio-visual equipment and materials are available in schools at all grade levels for the teaching of science,

such as projectors, TV sets, recorders, films, filmstrips, and tapes. Few schools (less than 20 percent) report the unavailability of any audio-visual materials. More often than not teachers report that audio-visual materials are not needed or are rarely used with the exceptions of films, filmstrips, and the overhead projector (41). Currently (1982) teachers register complaints that AV materials are wearing out and there are no funds for replacement. Over-all in 1980, 66 percent of schools reported financial resources barely adequate for providing a good education for students (42). Eighteen percent of the schools have sought to meet budget needs by increasing class size and 60 percent simply by reducing the funds for supplies and equipment.

Chapter 4. Human Resources for Science Teaching

A report summarizing the three National Science Foundation status studies of science education concludes that "the teacher is the key" to most of what happens in science instruction (43). Teachers make most of the decisions about the selection of textbooks, subject matter to be emphasized, and the teaching procedures that will be used, and they influence student attitudes toward a subject. The teacher and the textbook exist in a symbiotic relationship to influence what is learned.

Science Teachers in the Elementary Schools. Elementary school teachers in the U. S. are expected to teach all subjects of a grade

level in a self-contained classroom. They are trained as "generalists" and 50 percent report that their undergraduate training did not prepare them to teach science. Little is done in schools to correct the situation; 71 percent of school districts have no inservice programs in elementary science, and 64 percent no longer have science consultants assigned to elementary schools (44).

The average elementary school teacher (K-6) has been teaching for ten years and yet 16 percent state they do not feel qualified to teach science, and fewer than a fourth consider themselves well qualified. Nearly half of these teachers feel they need assistance in teaching methods and in obtaining information about instructional materials (45). Only 14 percent of the teachers in the elementary schools have attended a National Science Foundation sponsored institute. Elementary school teachers do not value and are not prepared in the subject matter and methodology of the Federably supported elementary science programs, nor do they understand the goals (46). One set of reviewers of the NSF status studies of precollege science concludes: "Although we found a few elementary teachers with strong interest and understanding of science, the number was insufficient to suggest that even half of the nation's youngsters would have a single elementary school year in which their teacher would give science a substantial share of the curriculum and do a good job of teaching it" (47).

Science Teachers in the Junior High School. The typical science teacher in the junior high school has taught for 11 years, and 50 percent have a degree beyond the bachelor's. Of these teachers 62 percent are males. At the time of this survey (1976-77), 44 percent of the teachers were carrying college work for credit. Most junior high schools are departmentalized with teachers expected to be specialists in the subject they teach. Of the designated teachers of science, 76 percent teach only science, and 24 percent teach other subjects in addition to science.

The most common preparation of junior high school science teachers is biology, although 33 percent have less than 9 college credits in biology. While most teachers teach general science courses they have academic depth in only one science field. The consensus among school administrators is that anyone can teach general science; however, 13 percent of the teachers state they are not qualified to do so.

Three-fourths of junior high school science teachers state they did not plan to teach in these grades, and 87 percent state they would have benefited from a college program that specifically prepared them to do so. Only 16 states have certification requirements for junior high school teaching. Certification requirements for the elementary school typically cover grades 1-8 and for the secondary school grades 7-12 (48). A recent survey of 538 colleges of teacher education revealed only 30 percent "offered programs at

any degree level for training middle/junior high school teachers." (49). Only 5 percent of teacher education institutions require a specific science methods course for prospective junior high school science teachers.

Secondary School Science Teachers: Teachers for secondary schools are expected to teach specialized subjects such as, chemistry, physics, biology, or earth science. Their qualifications are whatever is required by a college science department for graduation with a bachelor's degree. About half the teachers will have had a methods course in science teaching, and nearly all have done student teaching in a local high school. Several states have a "distributed" science major for students planning to teach. This major typically consists of a minimum of 10 semester credits each in biology, chemistry, and physics and qualifies the graduate to teach any of these sciences in a secondary school. The distributed major is used to meet the requirements of small high schools and to provide more teachers of the physical sciences in times of a shortage. Fifty-four percent of high school science teachers have at least a master's degree and 41 percent were taking a college course for credit at the time of the survey (50).

Only 27 percent of science teachers in the senior high school teach science exclusively, and 13 percent feel unqualified to teach one or more subjects to which they are assigned. Nearly half of these teachers want assistance in learning about new methods of teaching and in obtaining information about instructional materials.

The average high school science teacher has 16 years of experience and is 41 years old. Three-fourths of high school science teachers are men. The number of men and women teaching biology are about equal.

The Current Predicament of Science Teacher Supply and Demand. The common practice in schools is that all scheduled classes will have teachers regardless of their qualifications. The teacher demand and supply issue is meaningless unless one considers their qualification in terms of professional standards. A nation-wide study of science teacher supply in 1980 showed the following number of states to have shortages in these subjects: biology 7; general science 14; earth science 30; chemistry and mathematics 31; and physics 40 (51). Based upon a scale of 1 to 5 (considerable surplus to considerable shortage) the Association of School, College and University Staffing reported the 1981 national ratings as follows: mathematics 4.81; physics 4.41; chemistry 4.13; earth science 3.89; and biology 3.66 (52). In all subjects except biology the critical shortages for 1981 exceed those of 1980. A survey sample of 657 secondary schools, fall semester 1982, was made to determine the percent of specified science classes being taught by non-certified teachers (53). The results were:

Biology	20.60	Environmental Science	2.80
Physics	20.00	Ecology	.90
Chemistry	18.70	Anatomy/Physiology	.90
General Science	13.50	Astronomy	.60
Physical Science	11.00	Other Sciences	4.70
Geology	6.20		

A survey of 600 colleges and universities with teacher training programs revealed for the ten-year period, 1971-1980, 1) there has been a decline of 67 percent of science and 77 percent of mathematics teachers being trained; 2) of recent graduates certified to teach science a decreasing number accept positions in the schools (54). An immediate result of these conditions for the 1981-82 school year was that 50.2 percent of teachers hired to teach science or mathematics were unqualified by professional standards (55).

The number of new applicants for admission to teacher education programs in colleges was down 31 percent in 1981 (56). In 1979 the supply of teachers was smaller than that in 1978 in 36 states. High school seniors do not consider teaching a desirable career. A nationwide survey by the National Education Association in 1979-80 led to the estimate that of nearly a million college graduates, a little more than 8,000 students completed preparation to teach mathematics or a natural or physical science and it may be expected that no more than 6,000 will elect to teach (57).

In 1981 more than one-third of employed teachers stated that they "probably" or "certainly" would not choose the teaching profession again; this is an increase of 18.6 percent over the number in 1976 (58).

Teachers when asked if they would choose education as a career if they were starting over again had these reactions in 1981: 24 percent said "probably would not," and 12 percent stated "definitely not"; 22 percent would definitely choose teaching as a

career if they were starting over--females more than males, and elementary teachers more than secondary. The major causes of job dissatisfaction were: public attitudes towards schools 66 percent; treatment of education by media and student attitude toward learning 60 percent; salary 58 percent; status of teachers in the community 52 percent; student behavior 49 percent. Class size, facilities, and other factors had lower ratings (59).

The prospects for obtaining or keeping a sufficient number of highly qualified science teachers in the future seem slight under present conditions. Recent studies show that 1) teaching as a career is attracting more individuals with low academic ability than with high ability; 2) nearly seven times more teachers with low academic records remain in teaching past the age of 30 than those with high scholastic records; and 3) an increasing proportion of teacher candidates are being drawn from the lower socioeconomic population (60). Furthermore, an increasing number of prospective teachers are being trained in colleges least qualified to educate teachers and with the lowest admission requirements. Along with this data we should recognize that the percentage of teachers with master's degrees has more than doubled since 1961, from 23.1 percent to 49.3 percent, while the portion holding only a bachelor's degree has dropped from 61.9 percent to 0.4 percent (61).

The decline in qualified people entering precollege teaching is often attributed to the poor salaries of teachers compared with people in business and industry with the same amount of education as that of teachers. The mean of minimum salaries for classroom teachers in 1981 was $12,496 and the mean of maximum salaries

was \$24,472 (62). The mean average salary in 1981 for precollege teachers was \$17,209. Estimated salaries in industry for a person with a master's degree are: first year \$19,000 and 5 years experience \$25,000. Teachers with 20 years of experience earn \$24,500 while the worker in industry with 20 years of experience receives \$45,000 and earnings continue upward (63).

A study of 1980-81 beginning salaries for earth science graduates who entered high school or industry found that high school teachers at all degree levels earn less money. The industry range for AB/BS graduates was \$24,00-\$30,000, and MA/MS degrees \$25,000-\$32,000. Graduates taking positions in secondary schools received at the AB/BS level \$11,000-\$14,000 and for those with a MA/MS \$10,000-\$14,000 (64). A survey of 158 college placement centers for 1982 showed that the average starting salary for chemical engineers at the AB/BS level was, \$27,072 and for MA/MS graduates \$29,000 (65). A high school chemistry teacher could be expected to start at \$12,500-\$13,000. Whether a science graduate enters industry or federal or state government his or her salary will be above that of graduates choosing high school teaching.

One of the most serious problems in precollege science education is the preservice education of science teachers. In professional fields, for example medicine, engineering, or integrated systems, the practice is that the role these practitioners are expected to play shapes their education and training. The

education of precollege science teachers rarely meets this criterion (66). Seldom found are college science courses designed especially for elementary and junior high school teachers to teach them what they are expected to teach (67). The problem at the secondary school level is that teachers are trained as "researchers" in science rather than as "interpreters" of science and technology--the primary role of a high school science teacher (68). The limited use of the NSF funded science curriculum programs in schools is due in no small measure to the failure of college science departments to prepare teachers in ways that would be supportive of the new curricula.

The professional education of science teachers has long been criticized for the failure of college educators to train teachers as professionals. Typical programs of teacher training stress almost exclusively techniques without a philosophical and psychological basis appropriate for science education. The lack of effective communication between scientists, educators, and classroom teachers about problems and issues of common concern has restricted the improvement of science education over the past 75 years.

There are efforts to raise the quality of teachers in the U. S. One approach is to require new teachers to take competency tests on their knowledge of science and teaching methodology, much like those for the practice of medicine or law before certification. To date 19 states use teacher competency tests. Another effort is to set minimum scores on the Graduate Record Examination for admission to teacher training programs (69).

A frequent comment by science teachers is that "nobody seems to care." Ernest Boyer, Carnegie Foundation for the Advancement of Teaching, observes "that we Americans have always had a curious ambivalence about schools and teaching. We tend to exhalt education and demean the teacher." (70). A comment by President Dwight Eisenhower at the time of the release of the President's Science Advisory Committee report on Education for the Age of Science, May 24, 1959 bears repeating. "One subject discussed in the report warrants special emphasis--the importance of raising the standing of our teachers in their communities. Higher salaries are a first requirement, but we need also to recognize the great importance of what teachers do and to accord them the encouragement, understanding, and recognition which will help to make the teaching profession attractive to increasing numbers of first-rate people." (71).

Inservice Education and the Professional Development of Teachers. The need for inservice programs for science teachers to keep up-to-date in science and pedagogy has long been recognized as important. Except for the NSF supported institutes and conference programs of the 1960s and early 1970s inservice teacher programs have never been very effective in achieving their goals or meeting the perceived needs of teachers. It has been said that 'the most of what teachers have learned from inservice programs is to be skeptical of anyone bearing new science programs.' Professional development as a concept of continuing education has not been built into the teaching profession beyond that of obtaining credits (academic or otherwise) to gain an increase in salary.

Local inservice programs are rated as useful by nearly half of teachers in grades K-3, 36 percent in grades 4-6, 25 percent in grades 7-9, and 19 percent in grades 10-12. Teachers in secondary schools find meeting of professional societies useful, more so than elementary school teachers who rarely attend such meetings. Sixty percent of secondary school science teachers find professional journals a useful means for "keeping up" with their teaching field, while few elementary school teachers find them useful (72). The major professional journals in science education written for precollege teachers are:

- The Science Teacher (general)
- Science and Children (elementary and middle school)
- The American Biology Teacher
- Journal of Chemical Education
- The Physics Teacher
- Journal of Geological Education
- School Science and Mathematics (general)

These journals include articles about science teaching, reviews of new textbooks and audio-visual materials, how-to-do it articles, announcements of professional meetings, and sometimes research reports.

Despite many efforts to develop systematic programs of inservice education in the schools, they have rarely been successful. A frequent recommendation is the need to change tenure policies to include inservice study every few years in order to maintain certification.

The Foreign Experience: Teacher Education. Foreign governments referred to in this report (China, Japan, Russia, East and West Germany) have certain common attitudes and practices regarding the education of science teachers. The prevailing attitude is that a scientific/technological-oriented society needs teachers with vision and commitment--a sense of mission. The commitment is not only to science and technology as enterprises but also their importance for the economic progress of the country that will lead to a higher standard of living. The teacher has not only a responsibility to the student but also to the country.

Teacher education is viewed as a technical field requiring specialized knowledge in science, technology, and pedagogy. In these foreign countries there are identifiable institutions for teacher education, such as teacher universities, pedagogical institutes, normal schools, teachers' colleges and teacher education departments in the comprehensive university. During the 1960s teachers' colleges and normal schools disappeared in America as institutions specializing in the training of teachers. The responsibility for science teacher education in universities, especially for secondary school teachers, is difficult to identify if in fact it truly exists. Foreign countries are endeavoring to strengthen science teacher education, especially along the lines of the social functions of science and technology.

There are teacher shortages in these foreign countries specially in the physical sciences. The Minister of Education in China has

directed school administrators to cancel the required courses in physics and chemistry for the school year 1982-83 if the school does not have qualified teachers. Schools are to use the released time to increase time allotments for other sciences.

Interesting features of science teacher education programs in foreign countries are:

- Russia--an undergraduate research project in science is required of students preparing to teach in secondary schools. The project is reviewed by a science faculty committee much in the manner of a PhD dissertation oral.
- China--college students in their second year have a course in which they study and critique the subject matter, organization, and goals of precollege science textbooks, those they will be teaching from when they are certified. This course is offered in the science department of the student's major. University science courses for teachers are organized to match the topics found in precollege textbooks. Student teaching is supervised by a faculty member from a department of science and one from pedagogy. In China, beginning teachers have five years to prove they are effective in the classroom and if they are not, they are assigned to nonteaching duties in the school.
- Japan--inservice education is regarded as an essential part of a "teacher's life-long education." They believe that inservice education must be systematized and the

instructional program cumulative. This approach is in contrast to the American system of short-term programs such as workshops, institute days, and conferences. Hyogo University, beginning with fall of 1982, is offering a two-year in-residence program for science teachers with at least five years of experience. The title of the program is "Integrated Research on Education in Action." The purpose is to provide a new level of professional competence and distinction for teachers. In this program teachers will carry on research in science education with the aim of harmonizing their practical experience with research on the improvement of instruction, learning, or curriculum (73). The program is at the master's degree level.

The academies of science, science departments in universities, and individual scientists in foreign countries are more actively involved in pre- and inservice education of science teachers than is typical in the United States. The perceived problems in foreign countries regarding teachers are: 1) raising their social and economic status; 2) teacher supply, especially in the physical sciences and for the rural areas; and 3) improving methods of teaching.

Chapter 5. Science Education in Nonschool Settings

Science learning in contexts other than school has not been studied systematically. Information gathered in the 1976-77

National Assessment of Science indicates that about 40 percent of 13- and 17-year-olds do participate in out-of-school science activities such as having a science hobby, carrying out a project, or reading articles on science. Larger numbers (60 percent) watch science programs on TV, and 90 percent have visited a museum (74). Fragments of information gathered from the NSF funded national surveys on the status of science teaching indicate that at least two-thirds of science teachers do not make use of out-of-school science resources, such as museums, zoos, and nature centers in teaching science. A few teachers in the middle grades attempt to integrate science programs on TV, such as Wild Kingdom and Nova, with classroom instruction. Field trips of any kind are rarely taken because of problems of transportation, insurance, scheduling, and student management. Typically, very little effort is made by teachers to augment science instruction in schools with learning resources existing in the community or in the communication media.

Students appear to acquire a substantial amount of science and technology information in out-of-school settings. The extent and effectiveness of this "hidden science curriculum" is unknown, it just happens. We do know that 78 percent of the science museums (in 1979) offered instructional programs for children and 43 percent programs for teachers. In addition, 66 percent of all types of museums now offer educational programs for special audiences, such as preschool children 21 percent; gifted and talented students 14 percent; senior citizens 33 percent, handicapped persons 26 percent;

and adult public 38 percent. Attendance at science museums is about equally divided between adults and children. A sampling of 49 of the 140 science-technology centers and science museums showed a 13 percent increase in attendance over the three-year period 1975-77, reaching a combined attendance in 1977 of 28,292,803 (75). Attendance at the three Sea World marine parks exceeded seven million in 1981. The extent to which children attend science programs in state and national parks, use self-directed nature trails, read science books and magazines obtained in libraries, attend science or computer camps in the summer, view science programs on TV, and visit many other public science resources (aquaria, planetaria, children's museums, arboretums, community gardens, pet "libraries") is not known. The circulation of popular science magazines (Science '82, Science Newsletter, National Geographic, Discover, Science Digest and others) is on the increase. From studies of children's interests it seems quite evident that they like science in out-of-school environments more than in school. The extent to which self-directed learning in informal settings contributes to an appreciation of science and technology and a valid interpretation of natural phenomena and events is yet to be explored.

Science educators are in general agreement that schools should make a more direct effort to use the total science related resources of the community in teaching science. There is also a consensus that most of these out-of-school science activities could and should include parents. The educational goal of out-of-school science

activities is to introduce students to the possibility of having science and technology become a part of their intellectual use of leisure time. The popularity of "good" science magazines, the increased attendance at science museums, and the likely success of Disney's Epcot Center for adults suggest that an increasing number of adults are curious to know what science and technology are about. The number could be increased if teachers would make more effort to utilize these resources.

The Foreign Experience: Out-of-School Science. In the Communist countries in particular there are widespread programs of informal or out-of-school education. These programs serve two broad purposes: one is to provide opportunities for young people to explore their science interests on their own, and the second is to help adults appreciate the importance of science and technology for strengthening social progress. All of the Communist and high technology countries discussed here were devastated or defeated in a war less than 40 years ago or were engaged in a civil revolution. In each country a decision was made to modernize the economy by investing in scientific research and applying science and technological innovations in agriculture, industry, and health. The problem was to achieve these results with populations largely illiterate and ignorant about science. Two types of educational programs were devised: 1) a modern science program for young people in school; and 2) a massive effort of a different sort to educate the adult population about science and technology in order to speed up modernization.

China had the most difficult problems. Their adult population in 1950 was largely illiterate; schools were undeveloped; the economy was at the Third World level; the population was one billion; the government was unstable; scientific research, technological innovation, and industrial development were depressed. Following a series of National Science and Education Work Conferences in 1978, China began an all-out effort to achieve an enlightened citizenry in modern science and technology by informal educational means. Some of the developments in out-of-school science education since 1978 are as follows: (76).

- Television and radio: Two to three times per week stations carry popular programs on science, health, medicine or technological achievements. One program is always designed for young children. These programs are in addition to regular courses in physics, chemistry, and mathematics offered by the radio and TV universities. Television programs reach an estimated 30,000,000 people and radio over 800,000,000.
- Between 1978-80, 4,300 popular science books were published, excluding 30,000 science fiction titles. In 1980, 1,280 science and technical titles were published with total sales of 100,000,000. The Life of Albert Einstein and Mechanics by Ernst Mach were best sellers. Many popular science books are published in languages suitable for minority groups, such as, Uygun, Mongolian, Korean, and Tibetan.

- A national organization of popular science writers has been formed with a membership of 4000 and a publication schedule planned through 1985. The national government gives recognition and awards prizes for the best science writing each year. A first-prize award in 1981 was for the article "Sounding temperature with transistors" explaining transistor-thermoscopes. At the 1981 meeting of the association 60 papers were presented on ways to popularize science.
- In 1982 there are 111 popular science magazines with a circulation of 117,000,000 copies. Radio has a sales record of 1.9 million copies per issue. In 1981 a Chinese edition of the Scientific American became available.
- Of the 1,200 professional journals, magazines, and periodicals published in China 900 are devoted to science and technology.
- There are 105 professional societies that publish popular science materials or conduct forums for non-specialists.
- Renmin Ribao, the Party's newspaper (circulation 5,000,000) is one of 29 major newspapers that regularly feature columns on popular science. One daily paper, Kejibao, is devoted entirely to reporting science and technology news. China Peasant, a new publication in 1981 and the first newspaper written especially for peasants, carries two pages of science and agrotechnology news in each issue. For all

China's 283 daily newspapers (circulation 65 million) achievements in science and technology constitute news worth printing.

- China has three science film studios producing close to 300 films per year to popularize science. A documentary film, <u>Weasels</u>, was judged the best film of the year for 1980.
- The Communist Youth League sponsors a "science popularization month" for children. The objectives are to have children become familiar with the life of one scientist, read at least one science book, take part in making some product involving scientific knowledge, and develop a science hobby.
- Between 1978 and 1982 over 300 science popularization centers--museums, zoos, botanical gardens, nature reserves--were established. In addition 1,320 science centers were formed. These centers are similar to some of the U.S. science-technology museums where children have an opportunity to develop projects, hear stories, see films, and visit with 'real' scientists and engineers. Those students who complete projects enter contests and the winners go to the Beijing annual National Youth Scientific Exhibition. Here projects are again judged and winners are awarded cash prizes. Exhibits remain on display for three months to inspire other children to develop science projects as well as to stimulate adult interests in science. In connection with the scientific exhibition a National Youth Science Symposium

is held where papers on science and technology are presented. Teacher made laboratory equipment and other instructional aids are frequently a part of the youth exhibition.

- Summer science camps have been organized for students "who show excellence in science." Some of these are in the cities where students study museum exhibits, and others are located in the mountains and at the seashore.
- In 1981 a National Science Coaches' Association was formed. This is an out-of-school organization for "furthering interest in science and energetically cultivating youngsters' scientific qualities."
- In 3,800 people's communes throughout China, associations have been formed to popularize science and technology and to assist peasants or workers applying what has been learned. Where possible, before and after photographs are used to sway peasants from a practice based on superstition to one based on science. The slogan used is "rely on science rather than heaven."
- Youth Amateur Associations for Science and Technology are found in 1,320 localities. In these groups one can study mathematics, physics, chemistry, astronomy, geology, aeronautics, radio, navigation and other topics.
- Recently in major cities, science and technology achievements

are displayed in front of stores. The "street of popular science in Beijing" is lined with display cases and tables of science exhibits. Merchants along the street donate window space for additional displays. In small communities similar displays are found in factories and commune centers.

- National contests in mathematics, chemistry, and physics knowledge are held yearly to stimulate students to study well.
- Plays and recently an opera, Second Handshake, are based on the life and achievements of scientists.
- Libraries are being extended, especially in rural areas and stocked with books on science and technology. There are books for self-study, a new translation of the Encyclopaedia Britannica, how-to-do-it books for improving agriculture, sanitation, care of animals, and agrotechnology, and many others of a practical nature.
- Children's Palaces and Youth Guidance Centers are places where gifted students can receive added education in the sciences and technology and perform experiments. Students who are able to attend these centers are expected to explain to other children what they have learned about science and explain the results of their experiments.
- Selected pictures in science textbooks, such as the human circulatory system, can be purchased in a large format to be used at home by students to help educate their parents in some aspect of science.

- Forums, symposia, lectures and conferences on science and technology take place in large numbers throughout China. They occur in factories, on the open plains of Tibet, in fields, even in homes. All scientists and technical specialists are expected to contribute some of their time to the popularization of science.

There is not much coordination between these programs, they represent simply an all-out effort to achieve a national goal by whatever means possible. The goal is "modernization in agriculture, industry, national defense, and science and technology by the year 2000."

Chapter 6. Instructional Practices in Science Teaching

Teaching represents any activity on the part of one person intended to facilitate learning on the part of another. What is desirable to be learned is broadly defined in the goals and objectives of a syllabus or textbook. Outcomes of instruction are generally perceived as knowledge, skills, and attitudes. When one speaks of "scientific literacy" as a goal, it implies a body of scientific concepts, an understanding of and ability to use investigative procedures, and an appreciation of what is meant by research. Teaching for these goals rests in part on recognizing conditions that favor learning such as problem solving, building on past experiences of the learner, establishing relationships, and an unknown number of other processes. Research on conditions of

learning is the investigative field of the cognitive psychologist.

Whatever the method of teaching, whether a product of empirical research or folklore, "good" science teaching remains largely an art. It seems remote that "good" teaching can ever be described in scientific terms any more than can the practice of science. Both the process of science and the process of teaching are guided by a mix of intuition, logic, decisions, experience, insight, common sense, momentary circumstances, and likely a bit of luck. Teaching may be a somewhat more complicated enterprise than science because there is always the student, a unique and an uncontrollable variable. No two students bring the same background of knowledge to any lesson; they will have different ways of learning, different levels of motivation and academic interest, different values about what is worthy to learn, and furthermore, these and other factors exist in an infinite number of interactions. There are also matters of class size, social distractions, the academic climate of the school, and the influence of "the class just before yours." Teacher charisma, enthusiasm, and style of teaching are also known to influence what pupils learn (77).

There is considerable research on science teacher behavior in class situations. A review of nearly 1200 studies did not lead to a pattern of generalizable practices that could be described as those used by the "best" teachers for improving student learning or those used by "poor" teachers whose students fail to make progress (78). However, what has been learned from research on science

teaching, when properly applied, leads to more effective learning than "common sense practices." Common sense will tell us that skill in problem solving is more likely to result from practice in solving problems than from hearing a lecture on the subject. What common sense does not tell us is the developmental level at which most children are likely to be successful in solving certain kinds of problems. The results of research on learning show that students often have naive theories for explaining real world events, and these theories interfere with scientific interpretations (79). The amount of time devoted to studying a subject in most, but not all, instances increases achievement. Prior learning influences what is to be learned next. Unless what is taught makes sense to the student the barriers to knowledge and thinking are not crossed.

The recent development of the cognitive sciences involving psychologists, computer and artificial intelligence specialists, linguists, sociobiologists, neural scientists, educators and behavioral scientists who seek to generate a new theoretical framework for human learning, thinking, and instruction, may lead to a stronger scientific basis of the "art of teaching" (80). The adaptation of information technologies to educational practice also has implications for teaching procedures and learning (81).

Instructional Methods Science Teachers Use. Instruction in science is directed to the entire class as a unit with little attention to individualization either for slow learners or the

talented. In elementary science most instruction is of the tell-and-show type followed by seat work. "Discovery" learning encouraged in the Federally supported elementary school science programs is not common. In the upper grades the routine is one of assign lessons, lecture, discuss, give more assignments, and test at frequent intervals. Lectures and discussions make up most of what happens in a class. Slightly less than half of science teachers report laboratory or manipulative work as frequently as once per week. Teachers who have attended one or more NSF-sponsored inservice programs are considerably more likely than other teachers to use manipulative materials at least once per week (82). Teacher demonstrations are used by 38 percent of science teachers at least once a week. Library work, guest speakers, computer assisted and TV instruction are rarely a part of science teaching. However, more laboratory work and less book work is seen as desirable by both students and teachers (83). About half of the science teachers in secondary schools feel they have to spend too much time teaching reading.

Inquiry, process, or discovery teaching is not widely used in the elementary schools. The principal reasons given for not using this approach are: 1) teachers do not understand what should be done; 2) it takes too much time; and 3) it complicates class management and leads to discipline problems. In secondary schools the infrequency of laboratory work is attributed to class management problems, lack of time, and supply and equipment deficiencies (84).

Instructional methods used in science courses are mostly directed to getting students to learn a body of information that is contained in the textbook, and tests are used to determine whether they have done so. Grades represent the percent of assigned subject matter a student has acquired. The choice of instructional procedures by a teacher appears to be more a matter of finding ways to socialize students than finding ways to achieve the goals of science education. Socializing means maintaining discipline, eliciting cooperation, doing things on time, working for good grades, and much more that must be considered at best minor objectives for the teaching of science (85).

The findings of research on learning and the generally recognized goals of science education have little influenc on the way science is taught in schools. Furthermore, not all that is known about human learning has been synthesized and generalized in ways that can be used by teachers for the improvement of teaching. Science teachers repeatedly identify "learning about more effective teaching methods" as one of their greatest needs.

<u>The Foreign Experience: Instructional Practices in Science Teaching.</u> Not a great deal is known about the conduct of teaching in science classrooms in foreign countries. Observers get the impression that students do a great deal of memorization. Whether the practice is greater than in American schools is a moot question.

In most foreign countries there is a shortage of science teaching equipment in terms of U. S. standards. While this is a problem that hinders student performed laboratory experiments, individual laboratory work is not as highly valued as in the U. S. In foreign countries more effort is put into perfecting teacher demonstrations, and students spend more time on "exercises." An exercise is a search for practical applications in industry and agriculture of science concepts acquired in class.

The following generalizations represent as nearly as possible concepts of instruction in selected foreign countries:

- Instruction not only serves to assist students in learning and applying science, but also in developing skills for independent learning.

  1. Topics are taught with an outward view of the subject that stresses the application of science and technology to industrialization as well as their role in social affairs.
  2. Homework, as means for independent study, begins in the early grades at one hour per day, and increases to four or more hours in the secondary school.
  3. Instruction is teacher centered with much of the class time used for explaining the subject matter, in addition to encouraging and helping students to master assignments.

4. Students are encouraged to work together and to assist each other in learning.

- With the exception of Japan, in most countries special provisions are made for gifted and talented students. The Japanese take the position that what is good for the talented student is good for all students, and all should strive for excellence(86).

    1. Special schools, classes, and programs make it possible for talented students to be challenged.
    2. Accelerated passing from one grade to another, schools for the gifted ("key" schools in China), research opportunities outside of school, specially designed courses, tutoring of other students, the examination system, and early admission to college are used to develop talented students.

Chapter 7. Precollege Students: Science Achievement and Attitudes

Science Achievement. The student in a science course is there to learn. What is learned by students, across the country, was first explored in a systematic way in 1969 by an agency established for this purpose, the National Assessment of Educational Progress (NAEP). Nationwide assessments of educational achievement in the sciences were made in 1979-70, 1972-73, and 1976-77. The sampling each time included students in the elementary school (age 9); the junior high

school (age 13) and the senior high school (age 17). Some test items were carried over from previous assessments making it possible to recognize changes in achievement.

Results from the three national assessment tests covering the period 1969-1977 show an overall decline in science scores from one test to the next. The declines were statistically significant between the first and second tests for all age groups, and on the third test for 9- and 17-year-olds. Declines in the biological sciences were less for 9- and 13-year-olds and greatest for the 17-year-olds. The steady decline in scores for the physical sciences was significant for all age levels (87).

The decline in science performance was not equal for all sections of the country or all populations of students. Groups that have tended to perform above the national level for each assessment are: (88).

- Students in the Northeastern region
- Nine- and 13-year-olds in the Central region
- Male students
- White students
- Students who have at least one parent with post high school education
- Students in advantaged-urban communities
- Students in suburbs of big cities.

Groups across all age levels which have tended to perform below the national level in each science assessment are:

- Students in the Southwestern region
- Female students
- Black students
- Students whose parents have not graduated from high school
- Students in disadvantaged-urban communities
- Students in big cities.

Some groups across all age levels have tended to show little, if any, deviation from the national level of achievement. These are:

- Seventeen-year-old students in the Central region
- Students in Western states
- Students in medium sized cities
- Students in smaller places.

It is evident that socio-cultural factors play a significant role in science achievement over and above conditions associated with schooling. As students grow older, socio-cultural factors seem to exert a greater influence on science achievement.

Racial differences on NAEP science assessments decreased during the 1980s. "Typically, when achievement for white students declined black students declined less, when white students have improved blacks have improved more" (89). The greatest difference in science achievement among races is found at age 17. However, blacks at age 17 (1977 assessment) showed a more positive view toward science than white students. "Eighty-two percent of black

17-year-olds, compared to 58 percent of white 17-year-olds, think that science should be required in school; and 73 percent black 17-year-olds, compared with 54 percent white, think that science education in the long run is worth the expense and effort expended"(90).

The median male-female differences in science achievement for all age levels show males to perform progressively better than females--.05 percent at age 9, 1.7 percent at age 13, 3.0 percent at age 17, and 9.7 percent for adults based on the 1969 assessment (91). While scores for both sexes declined on the 1973 and 1977 science assessments, the gap between males and females remained constant. The achievement advantage of males over females in the physical sciences increases with age. This result is influenced in part by the fact that boys, more frequently than girls, elect to take courses in chemistry and physics. Questions on which girls do better than boys are those related to biology such as knowledge of the human body and test items related to sex.

Since 1967 there has been a consistent slippage from year to year in scores on the Scolastic Aptitude Test. In the period from 1967 to 1981, scores on the SAT mathematics section declined from 514 to 491 for males, and from 467 to 443 for females. Verbal scores on the SAT declined from 463 for males to 428, and for females from 468 to 420. In terms of a total score for both men and women the decline was from 958 in 1967 to 890 in 1980 (92).

SAT scores, both verbal and math, for college bound seniors intending to major in the natural sciences, engineering, or mathematics, have remained consistantly above the average of all college bound seniors. In 1981 total mean SAT scores for all college bound seniors was 980, for intended biology majors 905, for physical science majors 1056, and for mathematics majors 1028.

In the decade 1969-1979 the number of students taking College Entrance Board Examinations for advanced placement in science and mathematics increased from 24,300 to 49,600. The mean science and math scores for these students increased every year over that of the previous year. The top high school students in science and math appear to be getting better and better (93).

In 1981, mean scores on the SAT were practically identical with those of 1980. Results on the 1982 SAT, both verbal and math scores, rose for the first time since 1963 to a combined score of 893; however, this is well below the 1963 mean of 980 (94). The median scores for all males was 430 in verbal and 492 in math; and for all females, 418 and 443. However, it was gains by blacks and other minority students on the 1982 SAT test that were largely responsible for the first increase in the overall SAT average in 19 years. Black student scores in 1982 increased 9 points on the SAT verbal section and 4 points on the math, while whites gained 2 points on verbal and nothing on math. From 1976 to 1982, SAT scores for white students declined from 451 to 444 on the verbal test, and 493 to 483 on math scores. But during the same period black students'

scores on the verbal rose from 332 to 341, and for Mexican-Americans scores increased from 371 to 377; for other minority groups the scores declined (95).

For the first time, October 1982, the College Board released scores by ethnic groups. The median scores for blacks were 332 on verbal skills and 362 on math. The median scores for white students was 442 on verbal and 483 on math; for American Indians 373 and 415; Asian-Pacific American, 397 and 513; and mainland Puerto Ricans, 361 and 396 (96).

Student Attitudes About Science Courses. Motivation for learning science and for choosing a career in science or engineering tends to be related to one's attitude toward science. Attitudes and motivation are influenced by educational experiences as well as by social-cultural factors such as expectations of achievement--boys are expected to achieve better than girls in science and mathematics and do. The highest academic achievers in science have the highest motivation and this is true for both sexes (97). The research on student attitudes toward science indicates motivation is a product of an undefinable number of interacting variables including grade level, sex, student self-concept, teachers, conditions for learning at home and in school, race, socioeconomic status, success in learning, attitude of peers, circumstances of the moment, and other conditions.

The 1976-77 National Assessment of Educational Progress gathered information on student attitudes toward science (98).

Among the finding were these:

- More 9-year-olds expressed favorable attitudes toward science than 13- or 17-year-olds.
- About half of 13- and 17-year-olds expressed favorable attitudes toward science classes and science related careers.
- More 17-year-olds than 13-year-olds were supportive of the value of research in the sciences and had a clearer notion of what science is; this was true for both sexes.
- Males, however, were more likely than females to have favorable attitudes toward science and science-related careers.
- At the age of 17, the following groups reported more favorable attitudes toward science classes and science related careers than the nation as a whole: blacks, people living in the southwest, people living in disadvantaged-urban communities and those living in big cities.

The NAEP survey as well as other studies show that the peak ages for positive attitudes toward science are 12, 13, and 14.

In a nation-wide study of the status of science education practices in the U. S. Stake and Easley explored student reactions and attitudes toward their science courses (99). The most frequent comments (20-30 percent) of high school students describe science courses this way: 1) "courses were boring"; 2) "overemphasizes

facts and memorization"; 3) "subject dull and irrelevant to their lives"; and 4) "unrealistic assignments." Nearly three-fourths of the students felt that junior and senior year science courses are aimed primarily at students going to college, and half feel there should be courses for "below average students." Students generally (48 percent) do not think science courses are too difficult, but half feel it is harder to get good grades than in other courses. Sixty-one percent of seniors believe "scientific literacy" is a worthy goal of instruction, and 51 percent would require some type of minimum competence science test for graduation from high school. Nearly half of the students believe teachers want to teach "pure science," stressing only basic facts and ideas, rather than considering how science is used in everyday life. Students are not inclined to be highly critical of the quality of their high school science program, 44 percent rate the program very good and 46 percent satisfactory.

Seniors in academic programs (75 percent) more often rate the quality of their academic instruction as "good" or "excellent" than do seniors in vocational (60 percent) and general (55 percent) curricula. Two-thirds of the 1980 seniors agree that schools should have placed more emphasis on academic subjects (100). Students would like to have more laboratory work and opportunities to work on projects, and a third feel that individual students should receive more attention. Nearly 60 percent of students think the

public does not put a high priority on the teaching of science in schools.

Students were asked to consider the purposes of science education in terms of human, career, and knowledge values. They rated all three purposes to be of value, placing career first, followed by knowledge, and the human value not far behind.

Student preferences, interests, motivation, and desire to achieve in science are for the greatest part the result of social-cultural factors. The greater interest and achievement in science by white males compared with females and minorities are largely accounted for by cultural factors, rather than by genetic, neural, or hormonal conditions. Differences between girls' and boys' interests in science can be observed as early as the second or third grade. Parents tend to treat boys and girls differently and this is later reflected in children's interests. The decline in attitude and motivation toward science shown by girls at puberty is largely the result of sex-role socialization and gender intensification and is only slightly influenced by educational practices (101).

Favorable attitudes and attentiveness to science and technology by students are influenced in various ways by the socioeconomic status of the family, parental educational level, notions of occupational prestige, religious beliefs, and sex-role expectations. In families where science and technology are frequently discussed, students are more highly attentive to science and technology than

where such discussions are absent (102). "Attentiveness" is a measure indicating a greater interest and knowledge in respect to science than the public at large.

College bound high school students are more attentive to science and technology than noncollege bound. Both college and noncollege bound students are more attentive to technology than to science (103). College bound students appear to decrease in overall attentiveness during their high school years from grade 10 to 12. While there is broad support for science and technology, most high school students do not see these activities as a primary factor in national economic growth and social development. Neither the teaching of science nor the school science curricula are presently oriented toward broadening the student's concept of the place of science and technology in society.

The Foreign Experience: Achievement and Examinations. Differences in science achievement between students in the U. S. and the five foreign countries included in this report are unknown because these countries did not participate in the international study of science achievement. There will be a second international testing program in the spring of 1983. Forty countries are participating; Russia, China, East and West Germany are not.

Examinations in foreign countries are regarded somewhat differently than they are in the United States. The focus of all

science teaching is to have all students pass a state or national test. The essential features of the examination system are:

- General examinations are typically required at entrance to primary school, for advancement from primary to middle school, for entrance into the upper years of secondary education, for graduation from secondary school, and for entrance into college.
- These examinations serve as "gateways" to the next level of education and as a means for steering students toward a vocational or an academic program.
- Examinations are used to set a tone of excellence in terms of student achievement and for promotion. There is no "social" promoting and little attention is paid to course grades.
- Each student is expected to achieve a high score on a comprehensive examination; he or she is in competition with the examination, not with other students.
- The attitude toward examinations is that there shall be no failures, all students are expected to achieve.

A week to a month is set aside for reviewing and preparing for the comprehensive test covering a course. In China, the time spent in reviewing a course is regarded as a period for "the consolidation of learning." This is the time when students are expected to conceptualize what they have been studying and endeavor to form principles and generalizations. In the process of "tying things together" the student is encouraged to read widely.

Chapter 8. Parents and the Teaching of Science

"Many of the problems of the schools can be solved only if parents become more involved than they presently are in the educational process.... A joint effort by parents and teachers is essential to deal more successfully with problems of discipline, motivation, and the development of good work habits at home and in school" (104). We can expect that to some degree parental attitudes toward science and science teaching will influence their support of science programs in schools and student performance in science courses.

Public attitude toward science and science teaching has only recently received serious study and thus only fragments of information are available. Studies of the public's attitude toward schools tend to deal with broad issues and policies and not specifically with subjects beyond that of the "basics" In general, the results of state and local surveys on priorieties in schooling rate science near the bottom on lists of 15-20 educational priorities. It is not so much that parents regard the study of science as unimportant but that other factors in schooling are more important. Parents regard "learning to think and reason" or "the ability to make thoughtful decisions" close to the top of what they think schools should accomplish. The study of science as a means for learning logical reasoning, forming valid decisions, or developing inquiry skills is apparently not what science means to parents--it is not what they learned in science courses.

A national survey on the status of science education in the United States gathered reactions from parents about science in the school curriculum (105). On the whole parents were not very concerned about the teaching of science. They did recognize it was important for students going on to college. "For the rest of the children it was important too but not much time should be spent on science if reading or computation skills needed working on." (106).

Slightly over 50 percent of parents agree in principle about what schools should be doing, but disagree as to how the job should be done. Another 21 percent disagree fundamentally on the aims and responsibilities of schools. Parents, 69 percent, more than school personnel, believe students should pass a standard examination as a requirement for high school graduation, and that a minimum competency level in science should be included.

Parents were asked to state their criticisms of science textbooks being used in local schools: 30 percent thought they were out-of-date, 24 percent they were poorly related to later courses, 20 percent there were too many trivial lessons, and 18 percent they were poorly related to tests used. Parents had few complaints about the reading level, difficulty, and sex biases in texts. Parents, 59 percent, were of the opinion that the science program in their high school was satisfactory, and 41 percent rated it very good. On the whole, 72 percent of parents had mixed feelings about the quality of education most young pe[illegible]t today. In the

teaching of precollege science, parents would like to see the major emphasis placed on career preparation, followed by the attainment of knowledge, and 18 percent rated the human purpose (liberal education) as the most important objective of science teaching. Teachers and school administrators believe knowledge to be the most important outcome of science education.

It seems reasonable to expect that parent attitudes toward science and technology influence their notions of a proper education in science for their children. The American public's general attitude toward science and technology continues to be favorable, though less so than in 1957 (107). In reality there are two publics, the 18 percent who are interested and informed about science and technology and the 82 percent who are less aware, less concerned, or who do not understand modern interactions of science, technology, and society. It should be noted that programs for the preparation of science teachers do not typically include information on science and technology in relation to social affairs. However, more than one thousand colleges and universities currently offer such courses, but not as a requirement for science teacher education (108).

Only 11 percent of the public see poor curricula and poor standards as the "biggest problems" of the schools in their community. However, 36 percent see the need for changes in the

curriculum to meet community needs. The most desired changes are: more emphasis on the basics, more practical instruction, and more vocational classes. Forty-two percent of parents would like to see more money spent on programs for children with "learning problems," and 19 percent think additional funds should be made available for the gifted and talented (109).

The Foreign Experience: Parents and Schools. Parents in foreign countries assume a more active role in linking the home and community with the school. They endeavor to provide a favorable learning environment at home and are generally supportive of teachers. In most countries the control of discipline problems in schools is considered as much a parent responsibility as that of the teacher.

Parents in foreign countries place a greater value on science education than parents in the U. S. In the foreign countries, parents are constantly reminded that a higher quality of life and economic progress will emerge from achievements in science and technology. This is the theme of much governmental propaganda and reflects national policies as well as school goals for an education in the sciences.

Chapter 9. Research and Development in Science Education

Research in science education extends over a period of about 75 years. Fewer than 200 studies were reported in the first 25 years, followed by 1000 in the next 25 years. In the six-year period 1970-75, 2,312 studies in science education were reported. Over-all there have been approximately 5000 investigations in science education. Half of these studies, mostly doctoral dissertations and master's theses, have not been reported in journals. Of the studies reported, a substantial percent conclude with a statement of "no significant difference" or "mixed results." Of the remaining number of studies a great many, due to sampling limitations, improper research design, or careless reporting, are not subject to replication nor are the results generalizable. This results in a very limited amount of research to answer questions about the teaching and learning of science.

Traditionally there has been little financial support for science education research beyond that provided from college or university general funds. In recent years funding from the NSF programs on Research in Science Education (RISE), Development in Science Education (DISE), and the NIE Teaching and Learning Research Grants has made serious research in science education a possibility. However, NSF funds available for science education research and development were reduced to nearly zero for 1982.

An Educational Resources Information Center (ERIC) and a Clearinghouse for Science, Mathematics, and Environmental Education (SMEAC) are located at The Ohio State University. Supported by the National Institute of Education Services, they provide a means for identifying sources of science education research. Most of the published research in science education appears in the Journal of Research in Science Teaching, Science Education, and School Science and Mathematics. In addition the European Journal of Science Education and similar journals in Australia and Japan publish research reports. In Europe, including England and Russia, in 1981, 68 research centers and institutes were identified that carry on research in science education (111). The number in the U. S. is not known, but it is smaller than a decade ago.

For the past eight years an annual summary volume of research in science education has been published in Science Education, developed with the cooperation of the National Association for Research in Science Teaching (NARST). NARST in cooperation with ERIC, publishes abstracts of papers presented at the annual meeting of the Association. A summary volume on Research in Science Education in Europe was published in 1977 (111).

In theory, the primary purpose of science education research is to contribute to raising educational achievement through disciplined inquiry. The results are viewed as important for deciding effective practice for teaching and learning, determining types of achievement, and establishing educational policies. The

rationale and pattern for educational research are sometimes compared to those of agriculture, medicine, and engineering. Each field stresses the matter of basic knowledge with a focus on application. Educational research tends to be highly complex because of human variability, cultural factors, and the societal context of educational problems and issues. To overcome some of these variables, educational researchers confine most of their studies to narrowly focused problems, with findings limited mostly to statistical inferences. There is a need for more broadly focused research in education (112, 113).

The new field of cognitive sciences offers promising approaches to the study of problems in science education. Two features distinguish this new paradigm. First, there is the infusion of new techniques for theory development, and second, new avenues for the study of mental activities such as the conditions of learning and knowing by means of computer generated models (114). The future of educational research, its perspectives and issues is currently of considerable professional concern (115).

This nation has always been committed to the goal of improving education. Because most educational problems are national in scope and include the entire population, the implication is that national policies and priorities are essential for productive research. These have been nonexistent or ill-defined with the result that educational research continues to be unfocused and fragmented (116).

Science education as an enterprise operates in a theoretical vacuum, without a conceptual framework or a philosophical base (117). For lack of a normative base it is difficult to interpret the results of science education research. Thus the research becomes little more than uncoordinated-fact gathering. The situation caused a committee appointed to study the issue to comment as follows: "We tend to forget that a firmer rationale for current practices might prove a greater boon to the vitality of educational efforts than would an entire compilation of suggestions about how to improve this or that pedagogical technique." (118). Without this "firmer rationale" the synthesis of existing research findings is greatly limited.

Science education research that might improve teaching has limited use in practice because the profession lacks an effective communication network. Furthermore, little has been done to translate research findings into teaching or learning practices that could be useful to the classroom teacher. Currently there are efforts to improve the situation but the results have not been studied (119).

Chapter 10. Problems, Issues, and Concerns in Science Education in the U. S.

There are a dozen or so national and an unknown number of state commissions exploring the status of science education in the United States. The need for reform and revitalization of

precollege science education has been recognized for more than a decade. A 1970 Report of the Advisory Committee for Science Education of the National Science Foundation called for "a second generation of courses and curriculum improvement programs." The Committee saw the task to be: "To educate scientists who will be at home in society and to educate a society that will be at home with science" (120). Since 1970 there has been a general criticism of public education in the schools. Emerging from public dissatisfaction with schools there has been an outcry for a return to the "basics," better discipline in classes, equalizing of learning opportunities, and a reversal of declining scores on national achievement tests.

A systematic study of the status of science teaching in the United States for the period 1955-1975 was initiated by NSF in 1976. Three studies were funded. Major findings are described in earlier sections of this report; for additional information see the published summary volume (121). The findings were reviewed by nine separate committees representing scientific societies, teacher organizations, and parent groups (122). Among the science education issues and concerns identified by the reporting groups were these:

- A balanced curriculum that includes fundamental knowledge as well as basic skills is recommended.
- The egalitarian philosophy reflected in educational practices during the 1970s has lessened student motivation.

- Support services for teachers are inadequate for the task of maintaining high quality science education.
- Present science courses fail to consider social implications of science.
- The inquiry or process approach used in teaching science over the past two decades is open to challenge in terms of teachability, learnability, and appropriateness as an educational objective.
- Much of the secondary school science curriculum is mismatched to the interests and needs of the majority of students who will not pursue scientific nor technological careers.
- The almost total commitment to a textbook as a source of knowledge is deplored. A related question is whether publishers are the most qualified persons for science curriculum development.
- Insufficient and improper training of teachers, both preservice and inservice, and the misassignment of teachers are blocks to achieving a quality education in the sciences.
- Modern instructional technology is not adequately used in schools.
- Financing the improvement of science teaching in schools remains a serious problem.
- Nontraditional or informal educational resources (museums, science and technology centers, etc.) should be more widely used for science instruction.

There was a consensus among the review teams that the goals and purposes for the teaching of precollege science should be re-examined in terms of a program of general education for all youth.

In response to a request by the President of the United States in 1980 the National Science Foundation and the Department of Education prepared a report on Science and Engineering Education for the 1980s & Beyond (123). The report is based on notes from six seminars arranged by the National Research Council. One phase of the report (Chapter 5) deals with concerns about science education in the secondary schools. It recognizes the need to:

- "Generate a sufficiently large pool of people, adequately educated in science and mathematics, from which may be drawn: (a) the relatively few talented and committed students who will go on to become professional scientists and engineers; (b) future non-science professionals such as lawyers, journalists, and managers who will require considerable levels of sophistication in scientific an technological matters; and (c) future technicians and members of the skilled work force who will pursue their occupations in an increasingly technological economy.
- "Provide all students with sufficient access to education in science and mathematics to allow them to pursue these different career options.

- "Equip all students with a sufficient understanding of the concepts and processes of science and technology and the relationships among science, technology, and society so they can function as informed citizens in our democracy."

In contrast to the science education reform of the 1960s, the advocates of the current reform want a balance emphasis upon science and technology. The 1960 improvement programs stressed "pure" science only. Recommendations for a 1980s science curriculum revitalization rather uniformly incorporate a societal context (science/social problems orientation). This is in contrast to the 1960 curriculum reform where the stress was placed on knowing the structure of discrete disciplines taught in terms of their theoretical dimensions and inquiry procedures. There is much attention focused on developing a science curriculum, balanced in terms of biological and physical science concepts, that would be required of all students. At the same time there is a concern about developing improved science and technology programs for the education of the gifted and talented students and for those who wish to test their interest in science and engineering careers.

Curriculum developers as well as science teachers are concerned about the teaching of technology. Consideration of technology in the modern science/social sense has not been a part of teacher education, is rarely a requirement for a college science

major, and appears infrequently in textual material for high school students. So far, no national commission or organization has provided a description or definition of a technologically literate person and what he or she should know or be able to do.

Teacher education in the sciences is of serious concern to those who have examined the status of science teaching. With the demise of normal schools and teachers' colleges early in the 1960s, secondary school teacher education in the sciences has been lost sight of in most colleges and universities. Undergraduate science departments need guidance in developing an appropriate education for a teacher of science in contrast to that of a future researcher. To assume there is no difference leaves the teacher with inappropriate training.

The majority of reports on the predicament of science teaching in schools have failed to consider the problems and issues with reference to the condition of secondary education as a whole. The major issue is a balanced curriculum including natural and social sciences as well as the humanities viewed as an organic whole (124).

More than a century ago Herbert Spencer in his essay on education raised the question of "knowledge of most worth" (125). Today, the issue is raised again. The overwhelming amount of knowledge in every field of science suggests new criteria for the selection of subject matter for courses in science need to be examined.

Now that knowledge is seen as having wider dimensions than intellectual enlightenment, some of these criteria may be outside the disciplines of science and include economic factors. Note the work of Machlup, Schultz and Denison (126a, b, c). Holzner has summarized the knowledge issue this way:

> "The dramatic increase in the reliance of contemporary societies on knowledge--scientific, technical, or professional--in the period since World War II, the often problematic role of expertise in contemporary public discourse, and the persisting problematic of ideology and rationality have given the sociology of knowledge again a central place in the sociological endeavor. Indeed, the sociology of knowledge as a critical inquiry into society's capacity to know and learn has rapidly become not only a theoretical but also a practical enterprise. Inquiry into the structure of societal knowledge systems, the social arrangements through which knowledge is acquired, stored, distributed, formed or distorted, and used or misused, is a matter of deep theoretical significance for social science. It also touches upon issues of grave consequence for the well being of society" (127).

In practical terms the issue for science education is the need to consider ways in which scientific and technological knowledge can be utilized by citizens for interpreting science based social

problems, and for making responsible decisions on these problems when required to do. There is another dimension to the knowledge issue. Now that microelectronics is making it increasingly possible for the educated citizen to have access to large amounts of scientific information, the development of skills for processing information becomes a matter of deep concern.

Past experience in science education indicates that few curriculum or teaching reforms influence a large sector of the education community, and practically no reforms have more than a modest tenure. Speculations about the causes of this situation center on the lack of public policy regarding education in the sciences and technology, the lack of an on-going policy making mechanisms, and confusion about science education goals. Unless a conceptual framework for an education in the sciences can be formulated that represents a modest degree of intellectual and moral consensus and commitment, there is little likelihood that desirable changes of any magnitude will take place in science education.

Chapter 11. Actions in Response to the Predicament in Science Education

Since there has been an awareness of the developing crisis in science education for a decade or more, some curriculum adjustments in schools have been made. It is not possible to determine the extent of these changes because new programs

enrolling less than one percent of the students (30,000) in the secondary schools are not reported in national surveys of school offerings and enrollments. NSF is currently funding a project "Search for Excellence in Science Education," to identify outstanding science programs that meet specified criteria. The survey is being coordinated by the National Science Teachers Association and conducted by the National Association of Science Supervisors and staff members of Project Synthesis. It is expected the report will be completed by spring 1983.

The most extensive science curriculum developments of the 1970s-1980s have been in environmental studies, including ecology, marine biology, and energy conservation. About 15 percent of students are enrolled in one or more of these programs. A national survey in 1979 identified 284 programs and projects in environmental education (128). The courses are typically more interdisciplinary, socially, and action oriented than conventional science courses. Where separate courses do not exist these topics are likely to receive expanded coverage in regular courses. Examples of these courses listed in the National Diffusion Network (NDN) are: SEA a marine science project; Project Adventure a physical education program including environmental topics; and Knowledgeable Action to Restore our Environment (KARE). The Biological Sciences Curriculum Study (BSCS) has developed a series of modules on the

environment and energy which can be adopted for use in conventional science courses.

Innovative textbook materials written with a specific consideration of emerging developments in science education include:

- Project Physics: the major ideas of physics are presented in a humanistic and social context; physics is related to other sciences and to applied science and technology. (Publisher--Holt, Rinehart, and Winston).
- Interdisciplinary Approaches to Chemistry: a series of modules relating chemistry to everyday affairs; includes selected topics from inorganic and organic chemistry, biochemistry, physical chemistry and nuclear chemistry. (Publisher--Harper and Row).
- Intermediate Science Curriculum Study: an interdisciplinary modular science program for preparing students in grades 9-12 who do not plan to major in postsecondary science to understand practical, real-world, science-related problems. (Publisher--Silver Burdett).
- Interaction of Experiments and Ideas: developed by BSCS as a second course in biology for students who wish to consider careers in biology. A previous course in biology, chemistry and physics is recommended. The 1983 edition includes sections on computer graphing, programing, and computer languages. (Publisher--Prentice-Hall).

- <u>Human Sciences Program:</u> produced by the BSCS; a modular curriculum designed for 10-14-year-olds. The curriculum includes topics from the biological, physical, and behavioral sciences--psychology and sociology. (Publisher--National Science Programs, Inc.).
- <u>Engineering Concepts Curriculum Project:</u> has developed a text--<u>The Man Made World</u>--for use in high schools which includes a study of technology and engineering concepts in the context of practical affairs. Considerable attention is given to the use of computers. (Publisher: McGraw-Hill Book Co.).
- <u>Science in Society:</u> is a course on the implications of science, industry, and technology for society. Developed in England and adapted to use in the U. S. (Publisher--Hienemann Education Books, Inc.)

The use of these textbooks in schools has been minimal. Teachers do not regard the materials as "science" and fear students will not be able to pass college entrance examinations from knowledge gained in most of these courses.

In recent years the notion of "magnet" or specialized schools has attracted the attention of the public. The concept of specialized high schools goes back to the beginning of this century with the founding of the Bronx High School of Science, manual arts schools, and high schools designated college preparatory. The recent expansion (1960-1980) of magnet or alternative schools was a

response to public demands for schools that would meet the needs and goals of particular groups of students, especially students who might profit from vocational training. In Quincy, Illinois the high school was divided into five subschools each offering a distinctive program. Philadelphia has over 50 alternative schools some with a science emphasis. Some magnet schools are distinguished by a style of teaching such as more individualized instructions, less formal class work, or student directed learning. Whatever the nature of a magnet school it is not meant for everyone, whether it be for academic excellence, vocational preparation, or the development of a talent (129). Over-all magnet schools have never enrolled more than 5 percent of students.

The issue as to whether science should be taught in special schools or be an integral part of the curriculum in a comprehensive high school seems to have no acceptable answer at the present time. Members of the Paideia Group recommend the elimination of all specialized training in schools (130). The legality of alternative schools has been affirmed, the educational validity is the subject of much debate (131).

The North Carolina School of Science and Mathematics (NCSSM), is unique as an alternative secondary school. It is a full-time residential school and draws its enrollment from high school sophomores throughout the state. Students selected for the school are "bright" and have a strong interest in science and technology.

The central purpose of the school is the cultivation of scientific talent. The curriculum is broadly designed to include a balanced program in the natural and social sciences and in the humanities. All students become involved in community services. Teachers have been selected not only for academic qualifications (nine have PhDs) but also for creativeness and skill in teaching.

Course offerings have been designed to provide both depth and breadth. Advanced studies are available in the sciences and mathematics including such courses as, calculus of several variables, ordinary differential equations; a second year chemistry emphasizing electrochemistry, nuclear chemistry, and chemical thermo-dynamics; genetics, biochemistry, microbiology, animal behavior, and others. In addition there are science courses taught in a societal context such as, bioethics; population, resources and environment; wisdom-revelation-reason-and-doubt is a course which seeks to link and integrate the worlds of science and technology, humanities and social sciences; and science and society through the ages. Extensive experience in working with computers is emphasized.

Instructional practices include independent study in areas of interest not offered in the curriculum: guided study programs for all entering students; mentor guided research and study consists of assisting professional researchers in nearby universities or industries; special seminars; individual project work; and a Saturday morning activities program that provides

opportunities for interdisciplinary experiences. These instructional practices are in addition to regular class work and the requirement of one hour of laboratory per week per class. The first graduating class of 120 students received the second highest number of National Merit Scholarships among all the high schools in the U. S.

The crisis in precollege science and mathematics education has inspired U. S. Congressional members to propose a number of bills for consideration in the 97th Congress. Most of the bills favor college programs of science but others provide for the revitalization of school science and technology education. As of September 10, 1982 the following legislation has been proposed:

- H. R. 5254 (Fuqua) National Engineering and Science Manpower Act of 1982. (Has been approved by House Science and Technology Committee.)
- H. R. 5540 (Blanchard) Defense Industrial Base Revitalization Act.
- H. R. 5573 (Stark) Technology Education Act. (Has been approved by full House.)
- H. R. 5742 (Skelton) National Commission on Science, Engineering and Technology Education.
- H. R. 5820 (Miller) Electronic and Computer Technician Vocational Education Grants Act.

- H. R. 5842 (Fuqua) NSF Authorization Act for Fiscal Year 1983.
- H. R. 6656 (Winn) National Science and Technology Revitalization Act of 1982.
- H. R. 6672 (Perkins) American Defense Education Act.
- H. R. 6674 (McCurdy) Mathematics and Science Education Act.
- H. R. 6775 (McCurdy) Precollege Mathematics and Science Teacher Assistance Act.
- H. R. 6930 (Heckler) National Science and Technology Improvement Act of 1982.
- S. 2349 (Hatch) NSF Authorization Act for Fiscal Year 1983.
- S 2474 (Bentsen) Scientific Research and Education Act.
- S. 2475 (Bentsen) Scientific and Technical Equipment Act.
- S. 2476 (Bentsen) Skilled Labor and Training Act.
- S. 2551 (Schmitt) NSF Authorization Act for Fiscal Year 1983.

Several cities and states are providing funds designated for the relief of problems of teacher shortage in science and mathematics. Houston, Texas, and Oaklahoma City are paying science and mathematics teachers higher salaries to keep them in service. Teacher unions and professional educational organizations are opposed to this plan. Kentucky will pay $3,500 per year to support a college student who majors in science or mathematics and takes a high school position upon graduation. Alabama has a similar arrangement. In neither case do students need to repay the loan if they go into teaching.

Several states are in the process of increasing minimum standards in science and mathematics for graduation from high school or for admission to a state college or university.

- Florida--3 years of mathematics (including one semester of computer literacy) and 3 years of science (two courses must have a laboratory component).
- California--3 years of mathematics (including one semester of computer science) and two years of science.
- Ohio--3 years of mathematics and 3 years of science.
- Nebraska--2 years of mathematics and 2 years of science.
- Mississippi--3 years of science and 3 years of mathematics.

Educators are aware that an increase in the number of courses does not assure that the <u>quality</u> of science and mathematics education will be increased. In the past five years enrollments in school mathematics courses have increased 14 percent, but in the same period of time courses in remedial mathematics in colleges increased 70 percent. In several states the recommended increases in science and mathematics requirements apply only to students planning to enter college. Unless the teacher shortage problem is resolved it is not likely that most states can make much progress in improving both the quantity and the quality of science and mathematics education.

There is much speculation about the need for a curriculum reform in the sciences if the educational goal in the U. S. is

to be scientific and technological literacy for all citizens. The American Chemical Society sees the need for "a nationwide effort to persuade high school and college officials to provide meaningful courses in chemistry for the general student" (132). The National Association of Biology Teachers is exploring new perspectives for the teaching of biology that are more consistent with the social and cultural demands of the 1980s (133). The American Physical Society has proposed that efforts be made "to create new courses [in physics] to attract a wider variety of students to help combat the public's illiteracy in science" (134).

The thrust of the recommendation for the revitalizing of precollege science education is the development of "general education" courses for the non-specialist with the goal of scientific literacy. It is also felt that programs for students who wish to explore careers in science should also be strengthened, perhaps through advanced placement courses. Implied or stated by committees seeking to improve science education, is the need for more cooperative and continuing efforts between members of the scientific community and persons involved in precollege science teacher education.

Chapter 12. The Foreign Experience in Science Education

Introduction. Almost every nation now perceives the necessity to reformulate its program of science education to bring it into line with continuing advances in science and

technology and to assure its economic health and achieve a high standard of living. Success in attaining these ends rests broadly upon the intellectual competence and scientific literacy of a country's entire population. The base for scientific literacy rests with school curricula and public awareness programs that develop a modern concept of science and technology and their importance in life and social development.

This chapter highlights a synthesis of the rationales, goals, and educational practices of China, Japan, Russia, East and West Germany where science education reforms are taking place. The statements in the chapter extend references to foreign countries made in earlier chapters. The science education processes and practices are those that are typical over the five countries, major exceptions will be noted.

A Synoptic Overview of Science Education in Foreign Countries (135).

- Foreign curriculum developers have designed precollege science education programs that:
    1. relate science and technology to the human resource needs of the country
    2. portray science as a political way of life (Communist countries) for achieving socialism and a world outlook

3. stress the role of science and technology in industrial development
4. recognize the importance of a uniform science core program common for all schools
5. link science with other school subjects
6. relate science and technology to the productive work of individuals
7. consider science as a basic subject throughout precollege education and thus a requirement for all students
8. emphasize the significance of science and technology for the future economic development of the country and the welfare of citizens.

- Leadership for curriculum development in the sciences in most foreign countries is a designated responsibility within the structure of the national government.
  1. The Academy of Sciences, science institutes, ministries of science and culture, or ministries of education formulate the theoretical guidelines and the framework for science curricula, and supervise the writing of textbooks.
  2. Teachers have opportunities to suggest changes and additions to a curriculum based upon their experience in teaching the subject matter.

3. The centralization of curriculum leadership establishes the authority and responsibility for the regular revision of courses and for long-range plans.

4. The results of research on learning and instruction in science are a factor in curriculum development.

- Science is introduced in kindergarten and is a required subject at all grade levels from the elementary grades through the secondary school.

  1. Science in the primary school (through grade three) is informal, focused on nature study and natural phenomena. The methods of teaching used are those likely to make science enjoyable to children.

  2. Typically the formal study of science begins in the fourth grade and classes are taught by teachers trained in science.

  3. One or more specialized sciences--biology, physics, chemistry, geography (includes earth science)--are introduced in grades 4 or 5 and extend over a period of several years.

  4. A vertical organization of the curriculum provides opportunities to reinforce what has been learned in earlier grades and to teach topics at an increasing level of complexity corresponding to the intellectual development of the student.

5. Elective courses in science are rare, and when taken, do not replace a required course.

6. Major attention is given to illustrating the interconnectedness between science subjects, between science and mathematics, and between the natural and social sciences. Biology and geography are sometimes viewed as integrative subjects in which information from several sciences can be related in studying a topic or a concept.

7. The science core is required of all students and involves 10 to 20 percent of the time alloted for the total school curriculum. Typically, in terms of class hours, all students in these foreign countries upon graduating from the secondary school will have three times more hours of science than students in the United States who elect four years of science.

- In the five foreign countries there appears to be a large percent of students who like school and are motivated to learn science.

  1. Daily attendance in schools is high and discipline problems are low.

  2. The correction of school discipline problems is shared by parents and peers.

3. Striving to be a good student and to learn well is regarded as a "moral" obligation to assure the overall progress of the country.

4. With the exception of China approximately 90 percent of students complete the secondary school

- In most foreign countries (Communist countries in particular) students from the primary grades on engage in productive work.

   1. Productive work means useful work (not play) and its purpose is to develop an appreciation of the importance of work and labor.

   2. At the secondary school level, learning in the special subjects is combined with work experience in a related enterprise where possible. The underlying principle is one relating theory (mental work) to practice (physical work).

   3. Vocational training (defined as the skills and knowledge required for employment) in selected occupations, technical as well as para-professional fields, usually begins in the last two years of the secondary school and may extend for a year or so beyond high school.

4. Although all students are expected to have work experience, career choices are likely to be made at age 14-15 between a program of vocational training or preparation for higher education.

- Out-of-school or informal science education programs are designed to extend student appreciation of science and to develop mass scientific and technological literacy in adults.

  1. In countries with a uniform national curriculum, extracurricular programs are used to allow students to explore their own interests and to develop individual aptitudes.
  2. It is generally recognized that efforts to develop a highly scientific/technological based economy require the support of an informed public as well as trained specialists.

- Foreign governments believe that a major factor in realizing the goals of a scientific/technological oriented society is to have teachers with vision and extensive training in science and science oriented pedagogy.

  1. Teachers of science from the fourth grade upward are educated to teach one or perhaps two science subjects.

2. Teachers are trained in teacher universities, normal colleges, pedagogical institutes, or specialized programs in multipurpose universities.
3. Teacher education is viewed as a technical field requiring a background of knowledge and skills much in the manner engineers are trained for a specialty.
4. An examination on academic competence and an assessment of personal qualities are required for admission to teacher education programs, and an examination on science and professional competence at the completion of teacher training.
5. Science and pedagogical courses in colleges and universities required for prospective teachers are usually designed specifically to prepare teachers for the courses they are expected to teach.
6. Teachers enter active teaching on probation and usually must be recertified within a specified interval of time, typically 5 years.

- Inservice education is regarded as an on-going and essential part of a science teacher's professional life.
  1. Scientists and engineers, their academies and association, as well as colleges and universities have a continuing responsibility for teacher inservice education and for the improvement of science curriculum.

2. Pedagogical institutes, methodological and science centers, and science teaching specialists are expected to research problems of student learning and motivation, instructional practices, and curriculum design, and to share their findings with teachers on an ongoing basis.

3. Teachers have a professional responsibility for their own self-improvement by membership in science teaching associations, the reading of professional and scientific publications, and participation in curriculum improvement.

- Statistical comparisons of educational programs and practices in foreign countries with those of the United States.

  1. In the foreign countries selected for this report the school year approximates 240 days compared with 180 days in the United States. Their school week is 5.5 to 6 days, and the school day 6 to 8 hours, plus additional time in homework.

  2. The percentage of students finishing the secondary school, except for China, exceeds that of the U. S. However, the number of secondary school graduates in China per year approximates 4 million; in the U. S. the number is 3 million.

  3. The proportion of secondary school graduates entering college is the highest in the U. S. The proportion of students specializing in science and engineering in the universities (almost 50 percent) is highest in the selected foreign countries.

4. Foreign language requirements in schools are primarily for the purpose of qualifying students to tap the world's resources of scientific and technological information, rather than the U. S. emphasis on speaking a foreign language.
5. Parents in foreign countries assume a more active role in linking school and community with the total educational endeavor than in the U. S. They also endeavor to provide a favorable learning environment at home and support instruction in science and technology.
6. Geography in foreign countries is a required course taught at several grade levels in the elementary and secondary schools. It represents a blend of earth sciences, cultural and economic characteristics of different countries, and a study of plant, animal, and human ecologies. The courses provide a global perspective to science, technology, and world economic concerns.
7. Students in foreign countries have a class load of 6-8 courses per term, though few meet as many times as the usual 5 days per week typical in the U. S. Additional time is allotted for recreational activities and study.

8. National science and education policies are more precisely delineated than in the United States.

9. Technology as an enterprise and as a product for cultural development receives considerably more emphasis in the science curriculum than in the U. S.

<u>General Notes</u>. It should not be assumed that all educational policies and recommended school practices in these foreign countries work smoothly and effectively. Russia and China have many minority groups which add language barriers to achieving the educational results they desire. There are also great differences between rural and urban schools. What has been described here is most characteristic of urban schools. There are teacher shortages and economic problems in nearly all of these foreign countries. The newness of science and technology has not worn off in these countries.

The most outstanding feature of these countries is that they have definite national policies for education in the sciences. The policies include national goals in terms of economic progress, and individual goals in terms of intellectual and career development. The educational and scientific leaders have been able to interrelate science and technological education to a greater extent than school in the U. S.

References and Notes

1. Steelman, J. R. Science and Public Policy. Vol. 4. Washington, D. C.: Government Printing Office, 1947. pp. 95-107.

2. Watson, F. Brandwein, P. and Rosen, S. (eds.) Critical Years Ahead in Science Teaching. Cambridge, Mass.: Harvard University Press, 1953.

3. Hearings Before the Committee on Labor and Public Welfare United States Senate, 58th Congress, Second Session on Science and Education for National Defense. Washington, D. C.: Government Printing Office, 1958.

4. Ibid., pp. 293-309.

5. Representative publications on educational issues in the 1950s:

   a. The "Rockefeller Report" on Education. The Pursuit of Excellence. New York: Doubleday and Co. Inc., 1958.

   b. Cole, C. D. Jr. Encouraging Scientific Talent. New York: College Entrance Examination Board, 1956.

   c. National Educational Association. The Identification and Education of the Academically Talented. Washington, D. C.: NEA, 1958.

   d. Rickover, H. G. The Education of Our Talented Children. New York: Thomas Alva Edison Foundation, Inc., 1957.

e. Educational Policies Commission, An Essay on Quality in Public Education. Washington, D. C. NEA, 1959.

f. Koerner, J. D. (ed.). The Case for Basic Education. Boston: Little, Brown and Co., 1959.

g. Conant, J. B. The American High School Today. New York: McGraw-Hill Book Co., Inc., 1959.

h. Henry, N. B. (ed.) Rethinking Science Education. The Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. Chicago: The University of Chicago Press, 1960.

i. Journal of the American Academy of Arts and Sciences. DAEDALUS. Education in the Age of Science. Cambridge: American Academy of Arts and Sciences, 1959 (Winter issue).

6. For a description of the goals and subject matter of the Federally supported secondary school programs see Hurd, P. DeH. New Directions in Teaching Secondary School Science. Chicago: Rand McNally and Co., 1969.

7. A description of the innovative elementary science courses can be found in:

a. Hurd, P. DeH. and Gallagher, J. J. New Directions in Elementary Science Teaching. Belmont, Calif.: Wadsworth Publishing Co. Inc., 1969.

b. Karplus, R. and Thier, H. D. A New Look at Elementary School Science. Chicago: Rand McNally and Co., 1967.

c. Martin, W. T. and Pinck, D. C. Curriculum Improvement and Innovation: A Partnership of Students, School Teachers, and Research Scholars. Cambridge: Robert Bentley, Inc., 1966.

8. Hurd, P. DeH. New Curriculum Perspectives for Junior High School Science. Belmont, Calif.: Wadsworth Publishing Co., Inc., 1970.

9. P. L. 85-864, section 303 (a) (1). NDEA Act, 1957.

10. AAAS Commission on Science Education. Guidelines and Standards for the Education of Secondary School Teachers of Science and Mathematics. Washington, D. C.: AAAS Miscellaneous Publication 71-9, 1971.

11. AAAS Commission on Science Education. Preservice Science Education of Elementary School Teachers: Guidelines, Standards, and Recommendations for Research and Development. Washington, D. C.: AAAS Miscellaneous Publication 70-5, 1970.

12. Newton, D. C. and Watson, F. G. The Research on Science Education Survey. Cambridge: Harvard Graduate School of Education, 1968. (mimeo).

13. President's Science Advisory Committee. Education for the Age of Science. Washington, D. C.: The White House, 1959.

14. U. S. Commissioner of Education. Education of the Gifted and Talented. Volume I. Prepared for the Subcommittee on Education of the Committee on Labor and Public Welfare, U. S. Senate. Washington, D. C.: Government Printing Office, March 1972.

15. Science and Engineering Education: Data and Information, (1982:30) Washington, D. C.: National Science Foundation, 1982. p. 39.

16. Weiss, I. R. Report of the 1977 National Survey of Science, Mathematics and Social Studies Education. Washington, D. C.: Government Printing Office, 1978. p. 51.

17. Bowker, R. R. Co. El-Hi Textbooks in Print: 1982. New York: R. R. Bowker, Co., 1982. Source of all references on the number of textbooks in print.

18. Weiss. 1977. p. B-44.

19. Office of Scientific and Engineering Personnel and Education. Science and Engineering Education: Data and Information. Washington, D. C.: National Science Foundation, 1982. p. 10.

20. Quick, S. K. "Secondary impacts of the curriculum reform movement: A longitudinal study of the incorporation of innovations of the curriculum reform movement into commercially developed curriculum programs." PhD diss. Stanford University, 1977.

21. National Center for Education Statistics. Digest of Education Statistics 1976. Washington, D. C.: Government Printing Office, 1976. p. 15.

22. Adler, M. J. The Paideia Proposal: an Educational Manisfesto. New York: Macmillan Publishing Co., 1982. pp. 34-35.

23. Guenther, J. and Ridgway, R. "Where have all the minicourses gone?" Phi Delta Kappan, 64:1:69 (September, 1982).

24. Klein, M. S. "Two worlds of science learning: a look at the Germanies." in A Challenge for American Pre-College Education: Science Literacy in Japan, China, the Germanies and the Soviet Union. Washington, D. C.: AAAS. In press. 1983.

25. Beauchamp, E. R. Education in Contemporary Japan. Bloomington, Indiana: Phi Delta Kappa Educational Foundation, 1982.

26. McFadden, C. P. "Science education in the USSR." Science Education, 66:1:125 (1982).

27. The authors of the 1982 National Science Foundation publication on Science and Engineering Education: Data and Information chose not to report figures on precollege science enrollments.

28. a. National Center for Education Statistics. Summary of Offerings and Enrollments in Public Secondary Schools, 1972-73. Washington, D. C.: Government Printing Office, 1975 and 1976.

    b. Weiss, I. R. Report of the 1977 National Survey of Science, Mathematics and Social Studies Education. Washington, D. C.: Government Printing Office, 1978.

    c. National Center for Education Statistics. High School and Beyond: A National Longitudinal Study for the 1980s. Washington, D. C.: U. S. Dept. of Education, 1981.

29. Weiss. 1977. These figures were obtained from a transformation of Table 27 in Weiss to portray enrollment in terms of student-years for grades 10-12 only. Details in draft report of Project Synthesis to NSF, 1980. Appendix 1-65.

30. NSTA Personal correspondence, unpublished data (October 12, 1982).

31. College Entrance Examination Board. National College Bound Seniors 1981. Princeton: College Entrance Board, 1981. p. 14.

32. Ibid., 1981.

33. Bartholomew, B. R. Survey of School Programs and Practices: 1980. Washington, D. C.: National Education Association, 1980.

34. Jones, L. V. "Achievement test scores in mathematics and science." Science, Vol. 213, pp. 412-416 (July 24, 1981)

35. College Entrance Examination Board. National College-Bound Seniors, 1981. Princeton: CEEB, 1981.

36. All information on science facilities, equipment, supplies and related budgets was abstracted from a nation-wide study by Weiss. (1977). Chapter 7, unless otherwise indicated.

37. Rogers, L. E. Science Teaching in the Public Junior High Schools. Washington, D. C.: Government Printing Office, 1967.

38. Helgeson, S. F., Blosser, P. E. and Howe, R. W. The Status of Pre-college Science Mathematics and Social Science Education: 1955-1975. Washington, D. C.: Government Printing Office, 1977.

39. "The number of computers in the schools." Education Week, 2:5:11 (October 6, 198_).

40. Weiss. 1977. pp. 123-124.

41. Weiss, 1977. Tables B-73, 74, 75 and B-84, 85, 86, 87 and p. 114.

42. Bartholomew. 1980. p. 27.

43. DeRose, J. V., Lockard, J. D. and Paldy, L. G. "The teacher is the key: a report on three NSF studies," The Science Teacher, 46:4 (April 1979).

44. National Science Teachers Association. "Testimony to the science, technology and space committee of the commerce, science and transportation committee," U. S. Congress, April 19, 1982. p. 8. (mimeo).

45. Weiss. 1977. p. B-107, B-108.

46. Pratt, H. (ed.) "Science education in the elementary school". in N.C. Harms and R. E. Yager, What Research Says to the Science Teacher. Washington, D. C.: National Science Teachers Association, 1981. p. 89.

47. National Science Foundation. The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in U. S. Schools: An Overview and Summaries of Three Studies. Washington, D. C.: Government Printing Office, 1978. p. 19:3.

48. Hurd, P. D., Robinson, J. T , McConnell, M. C. Ross, N. M. Jr. The Status of Middle School and Junior High School Science. NSF SED 8015816. Vol. II, Chapter 2.

49. "Help wanted: teachers trained to teach young adolescents." Common Focus, 4:4:4 (Sept.-Oct. 1982).

50. Weiss. 1977. pp. 138-145.

51. State Department of Public Instruction, Iowa. reported in Education Week, 1:12:14 (Nov. 23, 1981).

52. Association of School, College and University Staffing. reported in Education Week, (February 17, 1982) p. 15.

53. National Science Teachers Association, personal correspondence (unpublished). October 12, 1982.

54. National Science Teachers Association. Congressional testimony, April 15, 1982.

55. Ibid. p.5.

56. DeRoche, E. F. and Kujawa, E. Jr. "A survey of teacher supply and demand in the west." Phi Delta Kappan, 63:8:586 (April 1982).

57. Guthrie, J. W. and Zusman, A. "Teacher supply and demand in mathematics and science." Phi Delta Kappan, 64:1:29 (Sept. 1982).

58. "Teachers are better educated, more experienced, but less satisfied than in the past: NEA survey." Phi Delta Kappan, 63:9:579 (May 1982).

59. NSF. Data Book 1982. pp. 93, 94, 95.

60. Vance, V.S. and Schlechty, P. C. "The Distribution of Academic Ability in the Teaching Force: Policy Implications." Phi Delta Kappan, 64:1:22-27 (Sept. 1982).

61. NEA Survey. Phi Delta Kappan. (May 1982).

62. Education Research Service, Inc. ERS Report. Part I. Scheduled Salaries for Professional Personnel in Public Schools. Part II. Salaries Paid Professional Personnel in Public Schools. Arlington: Education Research Service, Inc. 1981.

63. Kirst, M. Improving Math, Science and Technical Education. Sacramento, Calif.: California Commission on Industrial Innovation. Vol. 6, p. 14. July 1982.

64. Claudy, N. H. Mini-Manpower Survey 1981-82. Washington, D. C.: American Geological Institute. October, 1982. (mimeo).

65. Report of College Placement Council for 1982. Quoted in Campus Report, (Stanford University) 15:2:6 (Sept. 29, 1982).

66. See "Education in Biology." The Life Sciences. Washington, D. C.: National Academy of Sciences, 1970.

67. See "Recommended Standards for the Preparation and Certification of Teachers of Science at the Elementary and Middle/Junior High School Levels." Washington, D. C.: National Teachers Association. 1982. (mineo).

68. See suggestions in Guidelines, and Recommendations for the Preparation and Continuing Education of Secondary School Teachers of Chemistry. Washington, D. C.: American Chemical Society. 1977.

69. See NEA report on Excellence in Our Schools, Teacher Education: An Action Plan. Washington, D. C.: NEA, 1982.

70. Quoted in Education Summary. July 15, 1982. p.4.

71. President's Science Advisory Committee. Education for the Age of Science. Washington, D. C.: The White House, 1959. p. v.

72. Weiss. 1977. pp. 153-156.

73. Hisao Kamidera. The New Teachers' Training Program at Hyogo University of Teacher Education. Tokyo: National Institute for Educational Research of Japan. Occasional Paper 03/82. June 1982.

74. National Assessment of Educational Progress. Attitudes Toward Science. Denver: Education Commission of the States, 1979.

75. NSF. Data Book. 1982. pp. 43-48 and 53-54.

76. Quoted from "Developing scientific and technological literacy in the People's Republic of China." by Paul DeHart Hurd in A Challenge for American Pre-College Education: Science Literacy in Japan, China, the Germanies and the Soviet Union. Washington, D. C.: AAAS. In press. 1983.

77. Gage, N. L. The Scientific Basis of the Art of Teaching. New York: Teachers College Press, 1977.

78. Blazer, A. L., Evans, T. P., Blosser, P. E. A Review of the Research on Teacher Behavior Relating to Science Education. Columbus, Ohio: ERIC Information Analysis Center, 1973.

79. Resnick, L. B. "A New Conception of Mathematics and Science Learning." Talk at National Convocation on Precollege Education in Mathematics and Science, National Academy of Sciences, May 12, 1982.

80. Calfee, R. "Cognitive psychology and educational practice," in Review of Education Research. D. C. Berliner (ed.). Washington, D. C.: American Education Research Association, 1981.

81. National Science Foundation. The 5-Year Outlook in Science and Technology 1981. Vol. II. Washington, D. C.: Government Printing Office, 1981. Chapters 4 and 10.

82. Weiss. 1977. p. 120-121.

83. Stake, R. E. and Easley, J., et. al. Case Studies in Science Education. Washington, D. C.: Government Printing Office, 1978. p. 18:33.

84. Ibid. p. 18:68.

85. Ibid. p. 19:4-5.

86. Adler, M. J. This is the position taken by The Paideia Proposal advocates--"The best education for the best, is the best education for all." p. 6.

87. National Assessment of Educational Progress. Three National Assessments of Science: Changes in Achievement, 1969-77. Denver: Education Commission of the States, 1978.

88. Ibid. pp. 14, 15.

89. Burton, N. W. and Jones, L. V. "Recent trends in achievement levels of black and white youth." Educational Researcher. 11:4:10-14, 17. April, 1982.

90. Kahle, J. B. "Can positive minority attitudes lead to achievement gains in science? Analysis of the 1977 National Assessment of Educational Progress, Attitudes Toward Science." Science Education, 66:4:543 (1982).

91. NAEP. Male-Female Achievement in Eight Learning Areas. Denver: Education Commission of the States, 1974.

92. NSF Data Book. 1982. pp. 123, 124.

93. Jones, L. V. "Achievement test scores in mathematics and science." Science. Vol. 213, pp. 412-416.

94. "The seniors' slump may be over." Time, 120:14:87. (Oct.4, 1982).

95. "Minorities raise their SAT scores." New York Times. Oct. 14, 1982. p. 5.

96. "100-point lag found in blacks' S.A.T. scores," New York Times. Oct. 5, 1982. p. 12.

97. Maehr, M. L. "A synthesis of findings on sex differences in in science education research" (Research in progress) University of Illinois at Urbana-Champaign, 1982.

98. National Assessment of Educational Progress. Attitudes Toward Science. Denver: Education Commission of the States, 1979.

99. Stake, R. E. and Easley, J. et. al. Case Studies in Science Education . Vol. II. Washington, D. C.: Government Printing Office, 1978.

100. National Center for Education Statistics. High School and Beyond: A National Longitudinal Study for the 1980's. Washington, D. C.: NCES, 1981. pp. 13, 15.

101. Maehr, M. L. 1982.

102. Miller, J. D., Suchner, R. W., Voelker, A. M. Citizenship in an Age of Science: Changing Attitudes Among Young Adults. New York: Pergamon Press, 1980. pp. 190-195.

103. National Science Board. Science Indicators 1980. Washington, D. C.: Government Printing Office, 1981. p. 178.

104. Gallup, G. H. "The 13th annual Gallup poll of the public's attitudes toward the public schools." Phi Delta Kappan, 63:1 (Sept. 1981).

105. Stake and Easley. 1978. Vol. II. Chapter 18.

106. Ibid. Vol. II, 17:19.

107. National Science Board. Science Indicators 1980. Washington, D. C.: Government Printing Office, 1981. Chapter 6, pp. 158-179.

108. American Association for the Advancement in Science. EVIST Resource Directory. Washington, D. C.: AAAS Publication 78-6, 1978.

109. Gallup, G. H. "Gallup poll of the public's attitudes toward the public schools." Phi Delta Kappan, 64:1:37-50 (Sept. 1982).

110. Blansdorf, K. "Research institutes and centers for science education in Europe." Science Education, 66:3:495-501 (1982).

111. Frey, K. et. al. Research in Science Education in Europe. Amsterdam: Swets and Zeitlinger, 1977.

112. National Academy of Sciences--National Research Council. A Proposed Organization for Research in Education. Washington, D. C.: NAS-NRC, 1958.

113. The National Institute of Education. Educational Research: Limits and Opportunities. Washington, D. C.: U. S. Dept. of Health, Education, and Welfare, 1977.

114. "Cognitive psychology and education practice" in Review of Research in Education. D. C. Berliner (ed.) Washington, D. C.: American Education Research Association, 1981. pp. 5-6.

115. Farley, F. H. (ed.) "The future of educational research." Educational Researcher, 11:8 & 9. (October and November 1982).

116. Kiesler, S. B. and Turner, C. P. Fundamental Research and the Process of Education. Washington, D. C.: A Report by the National Academy of Sciences, 1977.

117. Hurd, P. D. Toward a Theory of Research in Science Education. Washington, D. C.: The National Science Foundation, 1978. (mimeo).

118. National Council on Educational Research, Reflections and Recommendations. Washington, D. C.: The National Institute of Education, 1978. p. 43.

119. National Science Teachers Association. What Research Says to the Science Teacher. Washington, D. C.: The National Science Teachers. Occasional issues.

120. Report of the Advisory Committee for Science Education. Science Education—The Task Ahead for the National Science Foundation. Washington, D. C.: NSF 71-13, 1971. p. 48.

121. Helgeson, S. L., Stake, R. E., Weiss, I. et al. The Status of Pre-College Science, Mathematics, and Social Studies Education Practices in U. S. Schools: An Overview of Summaries of Three Studies. Washington, D. C.: Government Printing Office, 1978.

122. NSF Office of Program Integration. What are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field. Washington, D. C.: National Science Foundation SE 80-9, 1980.

123. National Science Foundation and Department of Education. Science and Engineering Education for the 1980's & Beyond. Washington, D. C.: Government Printing Office, 1980. Chapter V.

124a. For thoughts in this vein see, Adler, M. J. The Paideia Proposal: An Educational Manifesto. New York: Macmillan Publishing Co., 1982.

b. Report of the Commission on Humanities. The Humanities in American Life. Berkeley: University of California Press, 1980.

125. Spencer, H. Education: Intellectual, Moral and Physical. New York: John R. Alden, Publisher, 1860.

126a. Machlup, F. The Production and Distribution of Knowledge in the United States. Princeton: Princeton University Press, 1962.

b. Schultz, R. W. Investing in People: the Economics of Population Quality. Berkeley: University of California Press, 1981.

c. Denison, E. F. Accounting for Slower Economic Growth. Washington, D. C.: The Brookings Institute, 1979.

127. Holzner, B. "Guest editor's introduction." Knowledge, Creation, Diffussion, Utilization, 4:1:3 (Sept. 1982).

128. Disingner, J. F. A Directory of Projects and Programs in Environmental Education. Fifth Edition. Columbus, Ohio: ERIC Science, Mathematics and Environmental Education Clearinghouse.

129. Symposium. "Alternative schools: a question of choice?" Phi Delta Kappan, 62:8:551-573 (April 1981).

130. Adler, M. J. 1982. p. 35.

131. Estes, N. and Waldrip, D. R. Magnet Schools: Legal and Practical Implications. Piscataway, N. J.: New Century Education Corporation, 1978.

132. American Chemical Society. Chemistry for the public. A conference report. ACS: Oct. 1978.

133. Hickman, F. M. and Kahle, J. B. (eds) New Directions in Biology Teaching. Reston, Virginia: National Association of Biology Teachers, 1982.

134. Memorandum sent to college and university physics departments from the presidents of the American Physical Society and the American Association of Physics Teachers, January 2, 1981.

135. The following publications provide more detailed discussions on foreign education than presented in this report.

   a. Hurd, P. D. Science Education in the People's Republic of China. Washington, D. C.: National Science Foundation, Science Education Directorate, 1981. (mimeo).

b. Klein, M. S. The Challenge of Communist Education: A Look at the German Democratic Republic. New York: Columbia University Press, 1980.

c. McFadden, C. P. "Science and Mathematics education in the USSR." Science Education, 66:1:123-137 (1982).

d. Troost, K. M. "Society and science education in contemporary Japan." in AAAS A Challenge for American PreCollege Education: Scientific Literacy in China, the Germanies, and the Soviet Union. Washington, D. C.: AAAS, 1983. (in press).